A PAVEMENT FEEDBACK DATA SYSTEM

by

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PREFACE

This report describes a conceptual feedback data system for flexible highway pavement design and is an extension of the research reported in Report 123-4, "Developing a Pavement Feedback Data System." It also represents a coordinated plan of action to activate the information subsystem identified in the initial project report 123-1.

Included herein is a discussion of the concepts of management information systems and their relationship to a pavement feedback data system (PFDS). Emphasis is placed on the collection and storage of carefully screened pavement data which meet strict essentiality criteria. The resulting data bank is a fundamental complement to the flexible pavement design system (FPS) now being pilot implemented in ten districts of the Texas Highway Department.

This is the twelfth in a series of reports emanating from the project entitled "A System Analysis of Pavement Design and Research Implementation." The project is sponsored by the Texas Highway Department in cooperation with the Federal Highway Administration, and proposes a systematic and comprehensive program to achieve improved pavement design methods.

Special appreciation is extended to Mr. Frank Yu for his technical advice and consultation in the area of systems analysis and computer programming. His efforts have been especially helpful in the resolution of numerous system automation problems and the development of workable file concepts for the proposed pavement data system.

The cooperation and assistance given by several Texas Highway Department and Center for Highway Research personnel are also sincerely appreciated. Messrs. Ben Barton, Tom Cartier, and Duval Jarl of the Texas Highway Department were particularly helpful in several phases of this research effort.

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LIST OF REPORTS

Report No. 123-1, "A Systems Approach Applied to Pavement Design and Research," by W. Ronald Hudson, B. Frank McCullough, F. H. Scrivner, and James L. Brown, describes a long-range comprehensive research program to develop a pavement systems analysis and presents a working systems model for the design of flexible pavements.

Report No. 123-2, "A Recommended Texas Highway Department Pavement Design System Users Manual," by James L. Brown, Larry J. Buttler, and Hugo E. Orellana, is a manual of instructions to Texas Highway Department personnel for obtaining and processing data for flexible pavement design system.

Report No. 123-3, "Characterization of the Swelling Clay Parameter Used in the Pavement Design System," by Arthur W. Witt, III, and B. Frank McCullough, describes the results of a study of the swelling clay parameter used in pavement design system.

Report No. 123-4, "Developing A Pavement Feedback Data System," by R. C. G. Haas, describes the initial planning and development of a pavement feedback data system.

Report No. 123-5, "A Systems Analysis of Rigid Pavement Design," by Ramesh K. Kher, W. R. Hudson, and B. F. McCullough, describes the development of a working systems model for the design of rigid pavements.

Report No. 123-6, "Calculation of the Elastic Moduli of a Two Layer Pavement System from Measured Surface Deflections," by F. H. Scrivner, C. H. Michalak, and W. M. Moore, describes a computer program which will serve as a subsystem of a future Flexible Pavement System founded on linear elastic theory.

Report No. 123-7, "Annual Report on Important 1970-71 Pavement Research Needs," by B. Frank McCullough, James L. Brown, W. Ronald Hudson, and F. H. Scrivner, describes a list of priority research items based on findings from use of the pavement design system.

Report No. 123-8, "A Sensitivity Analysis of Flexible Pavement System FPS2," by Ramesh K. Kher, B. Frank McCullough, and W. Ronald Hudson, describes the overall importance of this system, the relative importance of the variables of the system and recommendations for efficient use of the computer program.

Report No. 123-9, "Skid Resistance Considerations in the Flexible Pavement Design System," by David C. Steitle and B. Frank McCullough, describes skid resistance consideration in the Flexible Pavement System based on the testing of aggregates in the laboratory to predict field performance and presents a nomograph for the field engineer to use to eliminate aggregates which would not provide adequate skid resistance performance.

Report No. 123-10, "Flexible Pavement System - Second Generation, Incorporating Fatigue and Stochastic Concepts," by Surendra Prakash Jain, B. Frank McCullough, and W. Ronald Hudson, describes the development of new structural design models for the design of flexible pavement which will replace the empirical relationship used at present in flexible pavement systems to simulate the transformation between the input variables and performance of a pavement.

Report No. 123-12, "A Pavement Feedback Data System," by Oren G. Strom, W. Ronald Hudson, and James L. Brown, defines a data system to acquire, store, and analyze performance feedback data from in-service flexible pavements.

ABSTRACT

The complex character of highway pavements coupled with ever-increasing traffic volumes and variability of climatic conditions have made it imperative that service life data be collected and analyzed to guide the design of new and reconstructed pavements. The road test approach inevitably omits some important aspects of performance and the mechanistic approach has thus far failed to yield the rational design models sought for so long.

Development of a system to collect, store and analyze carefully selected performance feedback data from full-scale, in-service pavements is proposed to overcome the inherent deficiencies of the mechanistic and road-test research techniques. This report is a case study example of such a data system for the State of Texas, and the selected performance factors are basically the inputs to a computer-based pavement design system known as Flexible Pavement System (FPS).

The most logical and efficient method of storing, retrieving, and analyzing vast quantities of data involves a modern electronic computer system programmed to perform typical file processing and management information system functions for the highway design and research engineer. Particular care must be taken to prevent intrusion of excess or irrelevant data into the system since this soon leads to system overloading and breakdown. The needs of the potential highway engineer users must govern system development to insure responsiveness.

A fundamental decision must be made regarding the record control key for the data system so that data is tied uniquely to that segment of highway pavement it describes. While many methods of record keying are in common use, there is a strong argument for using the existing Texas method for this system with appropriate, minor modifications.

There are several sources of feedback data and the methods of acquisition must be tailored accordingly. While some data needs can only be satisfied by initiation of new, statistically designed sampling and reporting procedures, there are already in existence a number of automated data files containing

many factors specifically needed for the pavement design function. Explicit recognition of this fact allows design of interacting data files and elimination of duplication. A favorable environment for this kind of interaction has been provided for the Texas system by acquisition of the proprietary data handling system known as MARK IV. Files must be designed to readily accomodate data with important time and space dimensions. Analysis routines are necessary to give the file users meaningful data summaries from standard as well as custom-written mathematical models. Significant pay-off in the form of improved highway systems is anticipated from full implementation of this pavement feedback data system.

KEY WORDS: feedback data, computer, data acquisition, data analysis, data retrieval, design information, information retrieval, information systems, systems analysis, pavements, pavement management, research management.

SUMMARY

The data system defined in this report is a suggested plan for the discriminate acquisition and analysis of data needed to properly execute the Flexible Pavement System (FPS). The concepts of management information systems presented herein are applicable to any pavement design system, and the system defined may therefore serve as a model for eventual development of a comprehensive and integrated highway management system. Immediate application to the flexible pavement design system will allow checking of the design models and submodels, thus leading to development of new models/submodels as appropriate. Some basic management parameters are also included in the form of pavement performance factors and will serve to augment data now used by the District Engineer in his highway management program. A much more responsive data and information system is envisioned with no increase in personnel resources.

IMPLEMENTATION STATEMENT

The specific steps to practical application of these research findings are discussed in detail in Chapter 10 of this report. Two points merit emphasis: (1) implementation of a pavement feedback data system generally as outlined herein is absolutely imperative in an organized, methodical attack upon the pavement design problem, and (2) implementation of the proposed data system can be achieved without additional personnel by reordering priorities and reassigning resources to the acquisition and handling of only that data having specific functional uses. It may be anticipated that benefits will include improved pavement design procedures and a responsive management information system for the highway engineer.

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CHAPTER 1. INTRODUCTION

Highway engineers have always sought a rational pavement design procedure. Some have said that classical mechanics would soon provide better design equations, while others have pursued the non-mechanistic, road test type approach. Meanwhile, the nation's automobile and truck traffic has grown at a furious rate, and vast sums of money have gone into the highway system. The pavement structure itself has been no small investment.

Unfortunately, much of the Interstate System has begun to show early distress and the General Accounting Office, the congressional watchdog on federal spending, has criticized the pavement designer and his works (Ref 80). W. N. Carey, Jr., in his opening remarks to the Highway Research Board (HRB) Workshop on Structural Design of Asphalt Concrete Pavement Systems, Austin, Texas, December 7, 1970, reminded his colleagues of these facts and admonished that "we better hurry to get some rational answers" (Ref 37). He went on to observe that this situation "is no longer a minor skirmish - an interesting intellectual exercise - it is a serious situation for all of us and for American transportation."

The Systems Approach

Although the road tests have provided answers to some questions, there remain the many unknowns that were beyond the limits of these experiments. The past five years has seen a great deal of emphasis placed upon a coordinated, systematic approach to pavement design. A cooperative research program involving the Texas Highway Department, the Texas Transportation Institute of Texas A&M University, and the Center for Highway Research of The University of Texas at Austin, has been underway since 1968 to provide some systematic improvements to the entire pavement design and management problem. Project 1-8-69-123, "A Systems Approach Applied to Pavement Design and Research," has yielded a number of findings and conclusions documented in a series of reports (Refs 28, 40, 45, 47, 56, 66, and 90).

Scope of Report

One of the fundamental objectives of the project has been to develop an information subsystem to yield research information, design information and feedback data (Ref 40). Figure 1 illustrates the basic characteristics of feedback information network envisioned in Project 123. Some preliminary planning guides for a data system were provided previously by R. Haas (Ref 28), and this report is a continuation to describe a Pavement Feedback Data System (PFDS) to be initially implemented for flexible pavements only. However, the concepts and principles of Management Information Systems (MIS) presented herein are equally applicable to rigid (or any) pavement system. Figure 2 depicts the various elements of this report and their relationship to the Pavement Design System (PDS) that has evolved from the research efforts of Project 123.

Chapter 2 presents the why of a PFDS, with special emphasis on the feedback loop from real in-service pavement systems instead of experimental sections.

Chapter 3 summarizes the state-of-the art in Generalized Data Management System (GDMS) software development, while the vital aspects of data control and coordination are discussed in Chapter 4.

Chapter 5 goes directly to the heart of the Flexible Pavement System (FPS) design method and sets forth those essential factors for which data should be collected, stored and analyzed in the feedback loop.

Chapter 6 is a summary of the existing data files of the Texas Highway Department, with main emphasis on those factors of direct application in the FPS design procedure.

Chapter 7 discusses sampling procedures to acquire reliable and representative data, and Chapter 8 presents conceptual and actual versions of file structures within the proposed PFDS.

Chapter 9 presents some potential user interactions with PFDS and illustrates some typical information output from the system.

Chapter 10 is a detailed implementation guide suggested for use by the Texas Highway Department.

Chapter 11 contains conclusions and specific recommendations for PFDS-related research and administrative actions.

Symbol Description

OT - Operational and Technical Revision Statements
MTR - Materials and Tests Records
MR - Maintenance Records
TR - Traffic Records
PR - Performance Records
CR - Construction Records
R - Records
I - Input

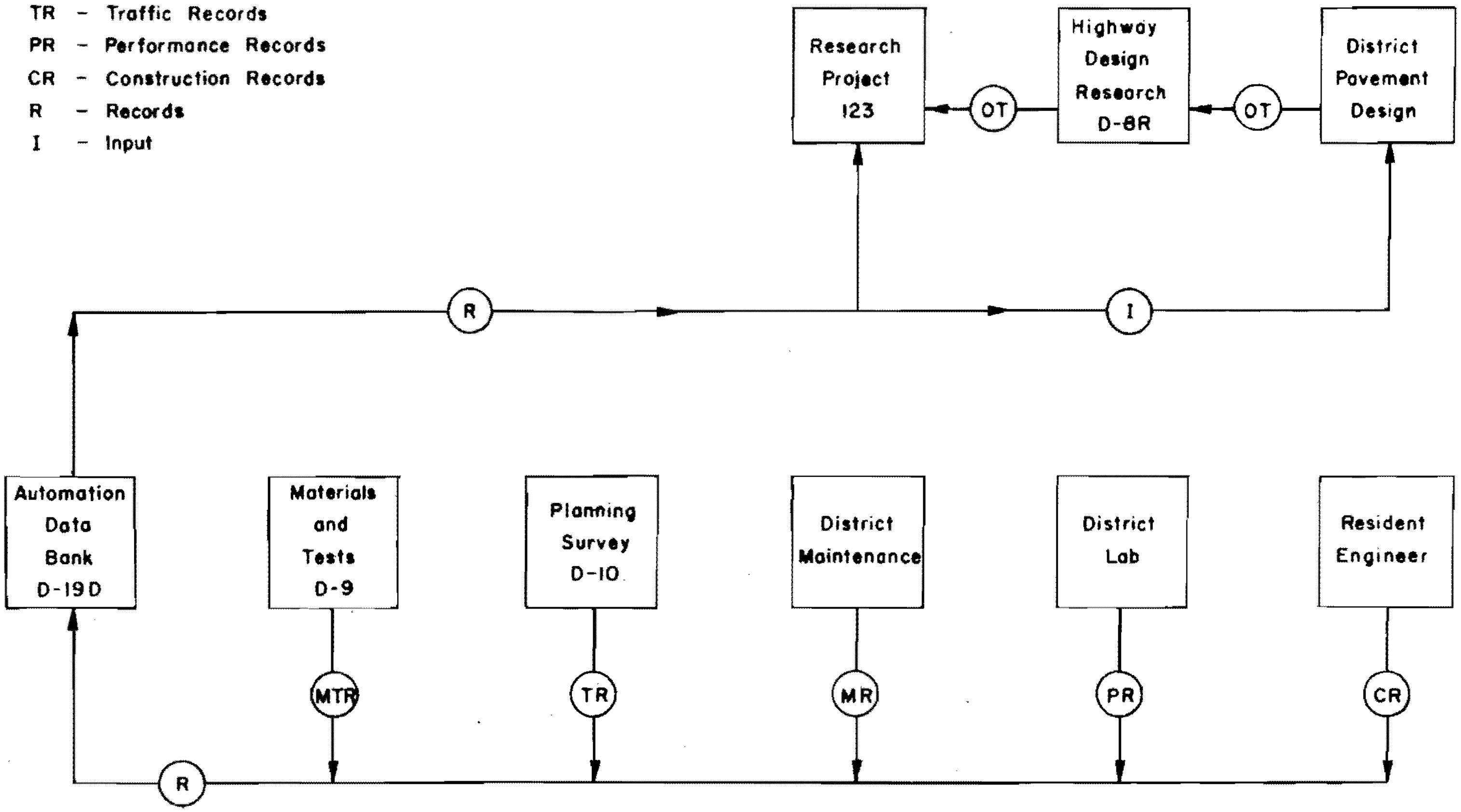

Fig 1. Feedback information flow (after Hudson et al, Ref 40).

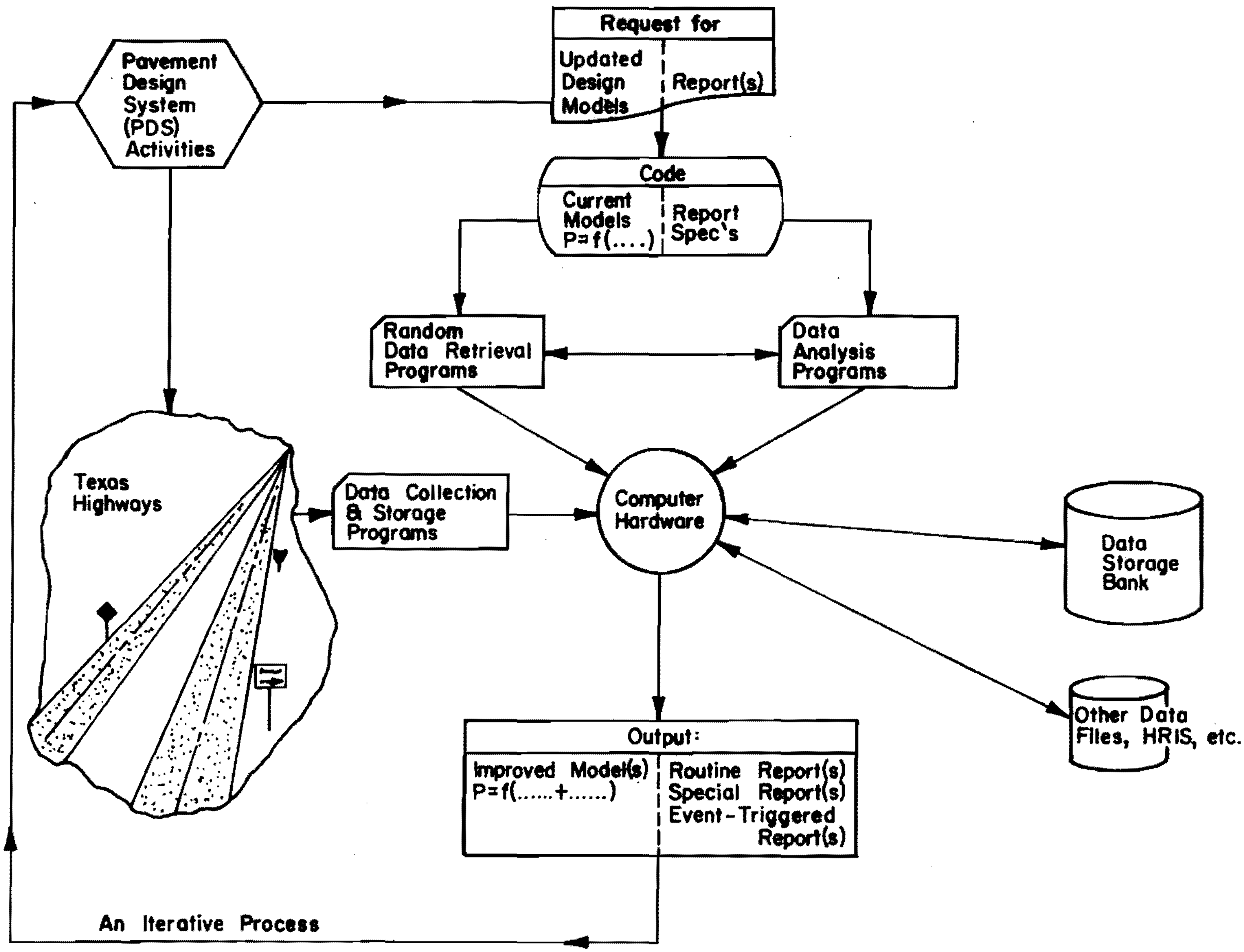

Fig 2. Scope of a pavement feedback data system (PFDS).

CHAPTER 2. DEFINITION OF A PAVEMENT FEEDBACK DATA SYSTEM

Expert Observations

In a memorandum dated October 23, 1962, D. C. Greer, Texas State Highway Engineer, advised his Chief of Design of the increase in research funding to be expected as a result of the Federal Aid Highway Act of 1962 (Ref 27). In directing the initiation of an expanded research program to properly utilize the increased funding, he stated:

> For many years, I have been convinced that the best research laboratory available to us is the Texas Highway System. .... It is possible that this is the time that we could take advantage of these funds that we will be required to expend to set up a research project to visit, inspect, and tabulate all information available on all concrete pavements built on the Texas Highway System in the past 25 years, together with the subsequent cost of maintenance and perpetuation. It is possible that such accumulation of data might then be handled through computers in such a manner as to give to us the tools whereby we might intelligently interpret the experiences of the past to guide us in subgrade and concrete pavement design in the future.

These words precisely describe the needed Pavement Feedback Data System (PFDS).

Nearly eight years later, Karl Pister, Professor of Engineering Science at the University of California, stated the mechanist's viewpoint of a PFDS (Ref 61). In his paper, he referred to systematic and continuous observations of performance of full scale pavements and stated:

> It is only through such a data acquisition program that any hope of pattern recognition will emerge to guide the formalization of operational rules leading to rational design. For example, without this, mathematical simulation of pavement systems, no matter how fascinating a game in itself, will remain precisely a game with very little pay-off to pavement systems.

Somewhat later in the same paper, Pister observed that rational but inadequate models of pavement behavior have been used successfully, primarily by allowing the engineer to use his judgment. He continued:

> In other words, the engineer is a short circuit of the rational design process. Our attempts should be, it would seem, directed toward continued use of the engineer in this role but supplying him with the best possible data upon which to base his judgments, thereby minimizing the possibility of irrational short-circuits.

The preceding descriptions of a PFDS by a practicing engineer-manager and an engineering mechanist leave little more to say by way of definition and purpose. The title, Pavement Feedback Data System, is considered a logical and appropriate summarization. In a sentence, a PFDS is an automated system containing select feedback data from actual in-service highway pavements, to be used for research, design, and management functions.

The scope and purpose of PFDS can be illustrated in another way. The 1970-71 Pavement Research Needs Report (Ref 56) gave a detailed problem statement for the six most pressing research needs in the pavement design area, as indicated by prior Project 123 work of trial implementation and sensitivity studies. A close examination shows that every one of these needs has an explicit PFDS element. This is also implied in Fig 3 where PFDS is shown in relation to the Highway Research Information Service, an operational data source designed for a specific purpose. The importance of this latter statement is discussed more fully later in this chapter and in Chapter 9.

Management Information Systems

With caution, PFDS can also be viewed as an engineer's version of a Management Information System (MIS), the computer-age concept of providing the manager with all the information he needs to make the best decisions (Ref 31). But MIS's have not had a highly successful history so far. Robert V. Head, president of the Society for Management Information Systems, observes: "An MIS is something like the weather: Everyone talks about it but nobody does very much about it" (Ref 33). He goes on to point out that a manager's need for information is "ad hoc;" it cannot be predicted. J. Gosden, MITRE Corporation, agrees and points out that the manager deals with the exceptional cases (Ref 25). When exceptional situations begin to recur, they begin to receive standard action and pass from the realm of the manager to that of the foreman.

PFDS Design Objectives

PFDS is similar to a MIS in its information potential but different in its data concept (see Chapter 9). One of the fundamental design objectives has been careful selection of relevant data factors with special emphasis on elimination of irrelevant data. This is regarded as a principal objective

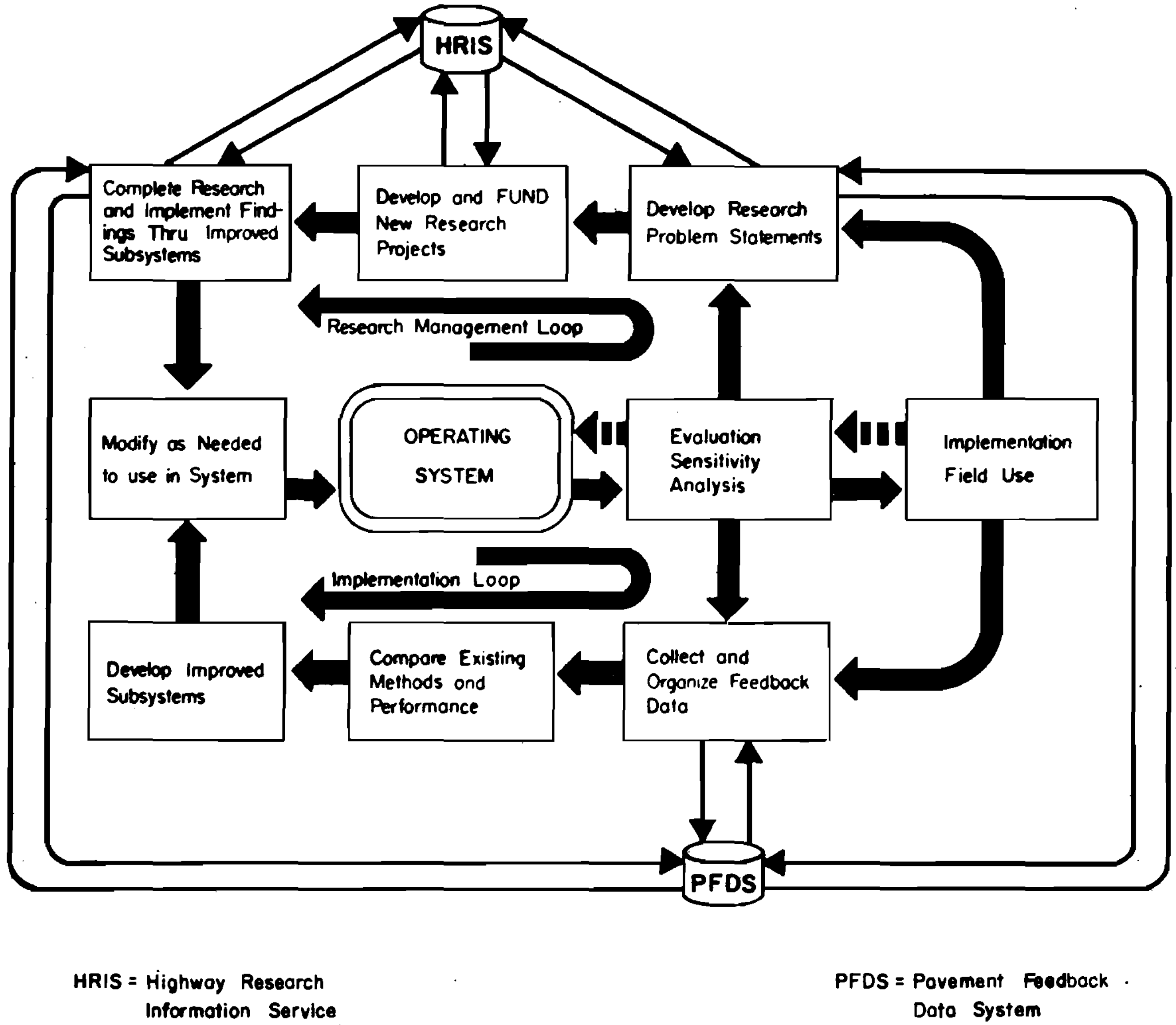

Fig 3. Interaction of PFDS with the operating pavement system.

omitted in the design of most MIS's (Ref 16, pp 401-411). When emphasis is only on supplying relevant data, almost exclusive attention is given to generation, storage, and retrieval of information. Changing the emphasis to elimination of irrelevant data results in a great deal of redundant material in relevant documents being purged. This is appropriate and helps to prevent the manager from being swamped with more data than he can possibly use.

Another fundamental and closely related PFDS objective has been to structure the system to serve a specific group of users, specifically, the pavement engineers. In addition to limiting the scope of the data realm, it assures development of a system for which "customers" exist and need not be generated. The Wisconsin Department of Transportation designed and built their Highway Network Data and Information (HNDI) System largely independent of a specific group of users. When the system became operational, they found that no user really existed and that the next necessary step was thorough indoctrination of field personnel as to the scope, character, and possible users of HNDI (Ref 86).

PFDS Development Phases

In his preliminary work on PFDS (Ref 28), Haas outlined the steps or phases in design and development as shown in Fig 4. No further comment is necessary except to call attention to two observations he makes:

(1) "Past experience has shown that it is very easy to underestimate the effort required to institute and maintain a comprehensive data system of this sort."

(2) ".... The implementation must be done in stages."

Additional evidence has been found during this continuation of PFDS research to reemphasize these points (Refs 12, 24, 32, 35, 46, 49, 54, and 81). M. V. Jones of the MITRE Corporation provides an excellent discussion of computerization of government data systems in Ref 46. He estimates from 20 to 72 months for accomplishment of all tasks inherent in computerizing a data system depending on complexity, size, personnel, resources, etc. He also cautions that undue haste in the initial steps of the process can complicate and delay completion of later tasks. Roger A. MacGowan of the Department of Defense Computer Institute quotes an expert opinion in Ref 54 to the effect that system

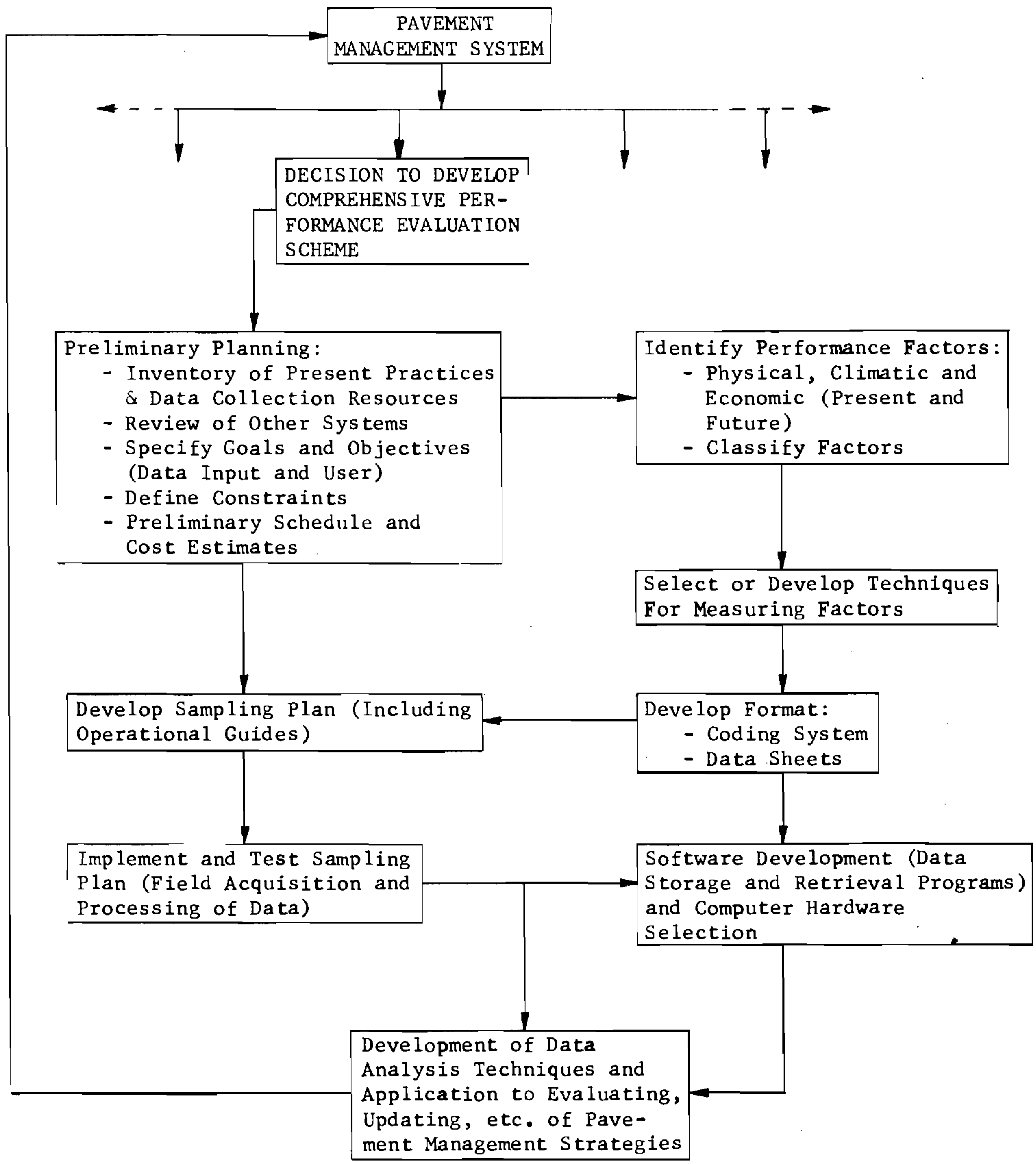

Fig 4. Major phases in developing and applying a pavement performance evaluation scheme (after Haas, Ref 28).

designers have found the management information task to be a "far more complex, far more difficult process than they ever anticipated."

The several phases of PFDS are all addressed to a varying degree in the following chapters.

CHAPTER 3. EVALUATION OF GENERALIZED DATA MANAGEMENT SYSTEMS

Hardware Constraints

When the automation of a data system is being planned, two important considerations besides the data itself are:

(1) hardware - the computer, and

(2) software - the computer programs.

The hardware part of this problem is already solved in that the Texas Highway Department is already equipped with some of the most powerful and modern computer equipment available. In July 1971, THD installed the first of two new IBM System 370 Model 155 computers. These units replaced IBM 360 Model 50 units, so there never was any question about what brand of equipment would be handling the PFDS data files in an operational environment. By going to the new System 370, THD acquired four times the internal operating speed of their previous 360 units (Ref 18). This new computing power has already begun to show its effect and backlogged computing work has been eliminated.

Generalized Software Evaluation

Hardware is important for reasons other than computing speed. It literally locks a user in on certain computer programs and methods (software); and this is especially true in the area of generalized data management systems (GDMS), or in equivalent terms, general purpose software. This became an important consideration in PFDS research because it was logical to first seek a general purpose software package for data management rather than write one from scratch. There has been a good deal of effort made in the past 15 to 20 years to develop a general system that can be adapted to any situation.

John B. Glore of the MITRE Corporation (Ref 24) describes the potential advantages of a GDMS as

(1) ease of use,

(2) fast response,

(3) economical use of computer equipment,

(4) sufficient flexibility to configure and reconfigure solutions to a wide variety of problems, and

(5) relatively little programming effort required.

Charles Kriebel, Carnegie-Mellon University, (Ref 50) states that there were about 50 such software systems commercially available in early 1969. Madill and Kuss of Simon-Fraser University (Ref 55) speculate that there are probably in excess of 100 existing software packages that perform data management functions. In any event, there is certainly a wide choice, both in vendors and price. A fairly recent summary (Ref 2) of file management systems by Altman, et al, reports that the commercial packages vary in cost from $10,000 to over $100,000.

With this kind of software marketplace, an effort was made to evaluate as many systems as possible for application to PFDS. The primary sources of information included Refs 7, 9, 21, 22, 24, 43, 44, 49, 58, 71, 79, 88, and 93. One of the difficulties encountered in this study was acquisition of objective information. Most available information is contained in vendor sales brochures and Jules Schwartz observes in Ref 54 that the seller's words have not been a notably accurate source for measuring the quality of software or its documentation. Objective evaluations by impartial authorities are limited.

Evaluation of 21 specific packages was undertaken by the Project 123 staff. All but five of these were promptly eliminated because of incompatibility with IBM hardware or the resident operating system, or because the package was no longer being maintained. The remaining five were (Appendix A)

(1) DM-1,

(2) COGENT III,

(3) MARK IV,

(4) GIS, and

(5) NIPS.

Detailed specifications for PFDS software were prepared and grouped as mandatory, desirable, and optional. An attempt was then made to match the commercial package capability against the specifications. The result was that no system, as then defined, met all of the specifications for PFDS (see Appendix B). A tentative conclusion was made that a best all-around answer would be to write the software package patterned after a system prepared for the Montana Highway Department (Ref 93).

An Operational Decision

Concurrently, the THD Automation Division, D-19, was conducting an evaluation of generalized systems to be used for several departmental functions of personnel, equipment, and fiscal accounting. Regular coordination was maintained between D-19 and the Project 123 research staff to share information and findings. In February 1972, D-19 decided to purchase the MARK IV/260 file handling system marketed by Informatics, Inc.

This decision by D-19 is regarded as a very discriminate selection and immediately marked a turning point in PFDS planning. In the evaluation conducted by the Project 123 staff, MARK IV was noted as the only system that was in wide commercial use and acclaimed by the users as capable of everything claimed by the vendor. Even Glore acknowledged it as an apparently successful "limited system" in his discussion of GDMS shortcomings (Ref 24). However, its initial cost of $40,000 was more than could be amortized at this time with PFDS alone. The use to be made of MARK IV in the entire Texas Highway Department is a completely different matter and adequately justifies such an expenditure.

MARK IV Application to PFDS

One of our first actions was acceptance of a D-19 invitation to look at MARK IV for possible application to PFDS. This first look revealed that the system has undergone constant improvement and now possesses capabilities not inherent in the earlier versions. One of the most important of these is an optional extra cost feature "Indexed Coordinated Files" that permits random access to the data base. Without this feature, the file can be processed sequentially only, a very slow and inefficient method of retrieving specific data items as needed. Random data access is considered an absolute must for PFDS and has always been a mandatory feature of the requisite software system. The Planning Survey Division (D-10) has indicated that this feature is essential for their file manipulations also.

Another extra cost feature of considerable value to PFDS is "Extended File Processing." This permits the simultaneous processing of nine files as compared with four in the basic MARK IV/260. This greatly improves processing time and efficiency and is also a valuable asset to D-10 operations.

It is concluded the MARK IV with the Indexed Coordinated Files feature can do the PFDS job very adequately. The system possesses several characteristics that make its use for PFDS very promising:

(1) Data fields are referred to by name.

(2) File record structure may be changed with little effort to insert or delete data fields. This is a powerful asset in any research endeavor.

(3) The coding forms are preprinted by the vendor and vastly simplify the use of the system (see Fig 28).

(4) The files created by MARK IV are fully compatible with the existing operating system (OS) and are readily available for accessing by custom-written analysis routines.

A Master THD System?

In summary, it is important to emphasize that MARK IV offers many advantages to PFDS as well as to the Texas Highway Department. Perhaps the most important of these is that it creates a common environment for all THD files, thus allowing them to readily interact and interchange information. This is a vital asset in PFDS functions as will become evident in later discussion. It is also important to THD because it standardizes the terminology for use of all data files, regardless of content or principal user. This may represent an important first step to master THD files, with the concomitant benefit of true information exchange and elimination of duplication.

CHAPTER 4. RECORD CONTROL KEY

Definitions

In the design of a computerized highway network data system, a method must be devised to uniquely identify data with a particular segment or point of roadway. The resulting device is a "record control key." If several data files are used to describe different highway system characteristics, it is important that the same record control key be used for all files in order to allow combined files processing and data analysis. This is a process called "correlation of data" and the control key is the common base of reference.

An analogy might be computer files on people in an organization. One file may contain personal data (height, weight, etc.) whereas two other files may contain previous employment records and current earnings data respectively. If we use the individuals' social security number as our record control key (in all files), we have uniquely identified the people in a consistent manner in our data files. We may therefore retrieve any combination of data pertaining to any particular person.

Methods of Location Control

The situation in regard to the highway system is similar but more complicated. Unlike people, our highway system is not a series of discrete units. Instead, it is a continuous ribbon of asphalt or concrete with constantly changing characteristics. Many different methods of location reference have been used to uniquely describe highway networks and William E. Blessing of the Federal Highway Administration discusses several in Ref 4. The principal methods are

(1) Route number and milepoint - Use of the federal or state highway number and a milepoint measured from some political or geographic feature such as state or county line. Field marking of the milepoint is done with uniformly or non-uniformly spaced mileposts. Data valid for only a point on a highway or for a given length of highway may be identified with this method.

(2) Reference posts - Unlike the milepost (or milepoint) method, reference posts each have a unique identification number without regard for the highway number. Central office records reflect the actual location of reference posts tied to route number, county, and milepoint from some starting point. Both length and point data may be tied to reference posts.

(3) Route special feature log - This method employs no field signing or posts. A straight line diagram or log is kept in a central office, showing the significant features encountered along the roadway. Highway intersections, bridges, county lines, etc. are the political, geographical, and man-made features with recorded milepoints that serve as the common base of reference.

(4) Coordinates - This method of position identification is exemplified by the international global method of latitude and longitude; a given latitude and longitude define a point on the earth's surface. On a smaller scale, state plane coordinates have frequently been used to locate specific points within a given state. This method necessitates several maps of the state along with a template or "Romer" to scale the coordinate locations (Ref 82). No field signing is used; data values are recorded in terms of north-south and east-west coordinates.

The Texas System of Data Control

An additional method not discussed by Blessing is that used in Texas, the Control Section numbering system. Originated about 1935, the control section method was intended to provide a master reference system within which all subsequent physical and cost data could be tied to specific segments of the highway system. The system has been applied universally in Texas to all road systems over the years until today, all of the 70,000 miles of Texas highway are so identified. The following definitions apply (Ref 76):

Control - a length of roadway 50 to 100 miles long with well-defined geographic termini,

Section - a sub-unit or length of "control," typically 10 to 15 miles long with well-defined geographic termini, and

Job Number - a sequentially assigned number within the control section to identify special maintenance and/or construction work to be performed on a given segment of roadway at a given time. The job number may cover all or any fractional part of a control section, and jobs extending over more than one control section are assigned a separate job number within each control section.

This Texas system is therefore a three-level locational identifier having a time (or event) as well as space dimension. Although the controls and sections were initially assigned in numerical sequence from west to east and from north to south, this uniform sequence has been interrupted by the irregular development of the state system. Today, there are 3,233 controls assigned and a total of about 8,000 control sections. This suggests that the "typical" control section is about 8-1/2 miles in length. It is important to emphasize that no portion of roadway has more than one control section number. However, frontage roads parallel to Interstate highways carry the same control section number as the Interstate.

Job numbers (the projects) vary in length and number per control section. The highest number assigned to date is 205; the typical job number length is 5 to 6 miles. The work they represent may vary in value from $1,000 to over $14 million. Special maintenance projects are usually lower dollar values whereas major construction and reconstruction are the high dollar project values. As might be expected, the high dollar value projects generally include major superstructures such as bridges, overpasses, interchanges, etc. It is also worthy of special note that each control section job number is carefully documented in a D-8 planning office set up specifically for this purpose. Pertinent data such as project description, limits, length, and cost are manually logged on standard Texas Highway Department forms.

Desirable Features

It should be understood that locational identifiers or record control keys for highway systems were not spawned by the computer, but they became imperative with the advent of computerized systems. In the development of such a data system, it is logical that a "best" record control key be sought. The attributes of such a key are

(1) simple to use both in field and office,
(2) absolutely unique for each section of roadway,
(3) based on some logical progression or sequence,
(4) relatively short symbol (code),
(5) meaningful symbol (code) without extensive reference documents (map), and
(6) really compensating for route changes, i.e., identity, location and length.

In PFDS research, a thorough review was made of all known existing methods and combinations. Some methods were strong in one area and weak in others; some were designed especially for item 6 above. Without resorting to any elegant techniques of evaluation, the various methods seemed to answer all desired attributes to about the same cumulative degree.

Because it is so different from the other methods, state plane coordinates deserve special comment. This method exploits the power of computer plotting techniques and possesses other characteristics so useful in many instances. It allows unique identification of a point rather than a cross section, with only two data values. In right-of-way and earthwork design situations, it allows computer processed plans, thus expediting the process and reducing manpower required. THD has a promising design system to accomplish just such work (Ref 3, pp 155-186). However, these many advantages are offset by the difficulty of using the method in the field. Other methods use the roadway centerline as one locational parameter, whereas state plane coordinates require two parameters of location, north-south and east-west coordinates. This requires elaborate control mechanisms not universally available and understood. Other problems recognized by John A. Vance, Toronto Transportation Systems Engineer, (Ref 82) are accuracy and data correlation. Thus, the coordinate method is considered a future improvement with much promise but not currently practical.

Blessing (Ref 4) concluded that the best method is a function of

(1) installation and maintenance costs,

(2) educational effort required, and

(3) flexibility of the system.

For Texas, a fourth factor had to be considered, namely, convertibility from control section to whatever new method was selected. Closely related to the educational aspect, convertibility specifically means that data now embedded in control section can be successfully tied to the new locational identifiers.

Record Control Key Selection

During the evaluation process, a visit was made to the Wisconsin Department of Transportation (WISDOT) to discuss their newly established Highway

Network Data and Information (HNDI) System. Oddly enough, WISDOT had been faced with the identical decision and had changed from log mile to the reference point method, backed up by state plane coordinates and "project numbers" (Ref 34). The back-up methods were intended to permit interaction of budget, accounting, and engineering design systems with the HNDI data base. Their experience was less than totally satisfactory. After considerable time and dollar expenditures, they were unable to assimilate the historical data on 12,000 miles of State Trunk Highway. This necessitated a resurvey of the system to obtain basic data. Furthermore, they have discovered that their reference point method occasionally yields some strange code designations, i.e., a "west" designation on a northbound lane of a divided highway (Ref 6). Their system employs the directional component in the key for a divided highway, and the anomaly occurs when the highway begins as a basic east-west roadway but runs north-south for appreciable distances.

Despite some deficiencies, it was concluded that the Texas control section method has far too many practical advantages to consider a completely new method. The most important advantages are:

(1) The basic data on 70,000 miles of existing highway are all tied to control section and are excellently maintained.

(2) The department procedures are now all based on control section.

(3) The control section method works.

It is concluded that the existing control section method with some additional features should be used for PFDS.

Modifications Required

Some fundamental computer file concepts for PFDS will be presented in Chapter 8, but it is important here to recognize two basic computer system features that should influence development of a record key. First, the system feature called "Indexed Sequential Access Method" (ISAM) allows retrieval of data without sequentially searching the data tape until the desired values are encountered. To do this, the system must be given the unique (and exact) key for the data item (example: Social Security number precisely identifies a person). The second feature is related and is suggested by the word "precisely." If the precise key is not provided, the system (ISAM) will not function (except in specially programmed instances). Suppose, for example, we have stored data on a bridge in our data system using the simple key of highway number and milepoint:

IH 35 72.553

Later, we desire to retrieve certain data on this bridge and our milepoint measuring device yields a reading of 72.549. The system will not retrieve the data record unless a special search mechanism is written in the program. The MARK IV data management system does not have such a special search feature. Therefore, it appears wise to avoid such precise components in the record key.

As mentioned previously, the key should be as simple as possible. Those who have worked with these features in data systems will quickly agree that the human error potential increases with complexity of the code, and the computer is completely intolerant of errors.

The proposed PFDS record control key is a concatenation of the following identification components:

(1) District - 2 digits maximum,
(2) Control - 4 digits maximum,
(3) Section - 2 digits maximum,
(4) Job Number - 4 digits maximum,
(5) Roadway - 1 digit maximum, and
(6) Lane - 1 digit maximum.

The district component (field) is suggested as an aid to rapid retrieval, especially for summary type reporting. The remaining fields are shown in Fig 5. The crosshatched area of the westbound lanes depicts an overlay, job number 100 in one control section and 50 in the other. We are concerned here only with control section 2374-2. Note that the roadway and lane codes are simple numerical designations left to right, looking in the direction of increasing milepoint. Paved shoulders are treated as separate lanes and numbered accordingly.

Before proceeding further with the example, two points in regard to job number should be emphasized. First, the permitted code is seen to be four digits whereas the highest number assigned to date is only three digits (205). The last digit is a decimal place, to indicate sub-units of a job number. For example, a job number code 2051 means 205.1, the first of two or more subdivisions of job number. The provision of this breakdown of job number is made

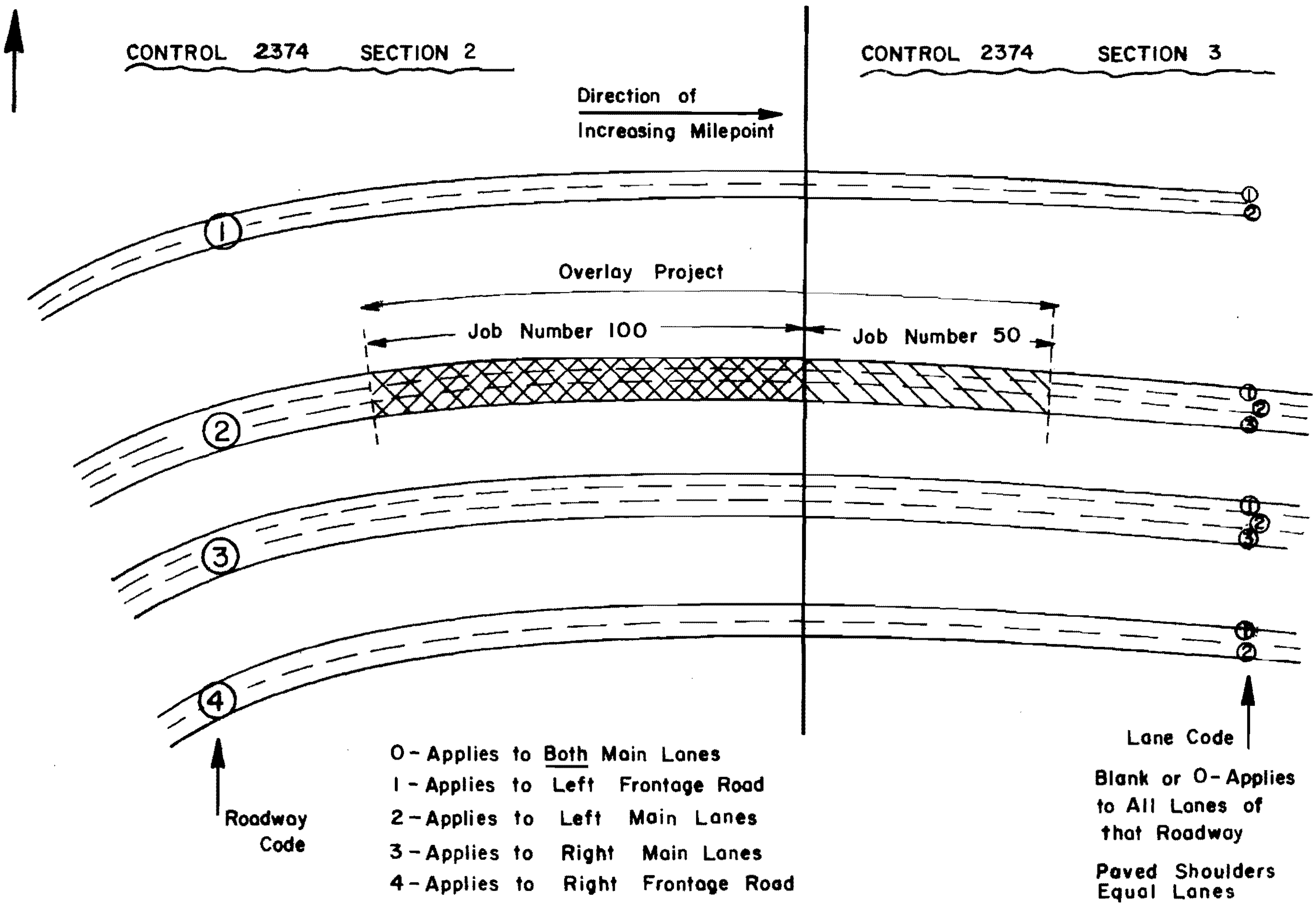

Fig 5. Illustration of record control key components.

necessary to properly identify changes in design, construction, or performance characteristics within a job number. In some cases, great variation in subgrade materials may necessitate a change in design within the job and such discontinuity must be recorded. In the vast majority of cases, the last place of the job number will be zero, indicating consistent design (or construction, etc.) for the entire job number length. In our example in Fig 5, the numbers 100 and 50 mean that job numbers 10 and 5 are consistent designs for the entire length of the project (job number).

The second point is that the termini for job numbers are indicated by milepoints included in the data part of the record. These essential locational features are parts of a space and time component of the data record as explained in Chapter 8.

The illustration here depicts the most complex situation probably to be encountered in reasonable practice. If a future need is shown for collecting and storing data for elaborate geometric situations such as interchanges, etc., a refined keying method may be necessary.

The serviceability-performance diagram for our example in Fig 5 is shown in Fig 6. This is for the westbound lanes only. Complete reconstruction was done as job number 50 in 1960 and brought the serviceability index (SI) up to 4.2. In 1965, a seal coat was applied as job number 70. Performance dropped to minimum acceptable in 1967 and an overlay was placed as job number 100, the one shown in Fig 5. Another special maintenance job and an overlay are to be accomplished before complete reconstruction in 1981 as job number 220. The missing job numbers (60, 80, 90, etc.) are work projects of no consequence to the pavement engineer, such as painting centerline and edge stripes and repair of bridge railings.

The collated data records for this pavement segment are illustrated in Fig 7. The district is number 2 in this case. It is seen that each record contains data on a unique segment of roadway at a unique time (occurrence of event).

Some meditation on this system of record control will generate the question as to how succeeding data entries are made. For example, if one of the data fields is serviceability index (SI), we may wish to enter 10 such readings each year for 20 years on our particular road segment. These additional data values will be contained in a supplementary file with a record key basically

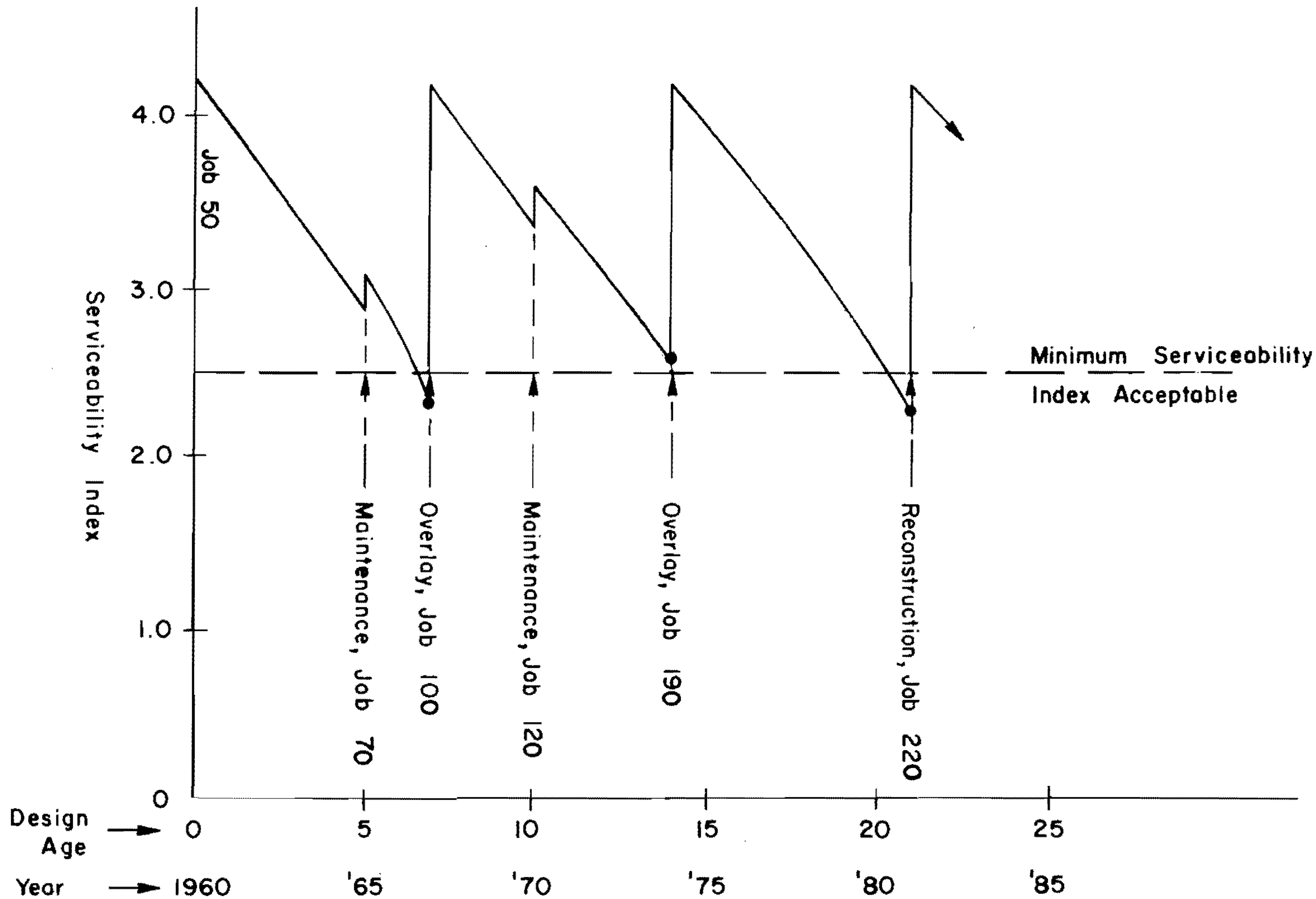

Fig 6. Serviceability-performance diagram for westbound lanes of control section 2374-2 (Fig 5).

District	Control	Section	Job Number ([illegible])	Roadway	Lane	Data Fields	Content of Record
02	2374	02	0050	2	0		1960 Reconstruction
02	2374	02	0070	2	0		1965 Maintenance (seal coat)
02	2374	02	0100	2	0		1967 Overlay
02	2374	02	0120	2	0		1970 Maintenance
02	2374	02	0190	2	0		1974 Overlay
02	2374	03	0050	2	0		"First" record in next sequential section; 1981 reconstruction of section 02 is not yet designed.

← Record Control Key Fields → ← Data Fields →

Fig 7. Collated data records for highway segment illustrated in Figs 5 and 6.

the same as the master record. Explanation of this situation is provided in Chapter 8; it is sufficient here to recognize that no radical changes in method are needed to meet such situations.

Although this proposed record control key is believed to be sufficiently definitive for PFDS at this point, it should be observed that one additional, one-digit, field will specify wheel path also. The concept used in roadway and lane designations is equally applicable with no difficulty. It is also important to mention in passing that the roadway designation coding proposed here is analogous to a data field called "Travel Class" in the D-10 Road Life (RL-1) file (see Chapter 6).

It is especially important to recognize an important benefit to be accrued with this proposed record control key. As discussed in Chapter 6, some especially applicable and valuable data files now being maintained by the Planning Survey (D-10) Division are keyed with control section and milepoint, and in some cases, with job number as an added field. This means that conditions are present for complete compatibility of files, i.e., PFDS with existing D-10 files.

Conclusions

As a concluding thought, it has been suggested that certain deficiencies in the actual use of the control section and milepoints (or mileposts) have made the method less than completely effective. For example, there are reported instances where mileposts have not been changed from the old south to north increasing sequence. Others have reported that mileposts are missing, thus making field locational identifications difficult or impossible. It is axiomatic that no system or method, however good in concept, can work if not fully implemented. Certainly, the system most easily understood has a better chance of working than a new method which must be learned. It then becomes a matter of making existing methods work in accordance with established directives.

CHAPTER 5. SELECTION OF PFDS ESSENTIAL FACTORS

Introduction and Background

The preceding discussion of management information systems (MIS) has stressed simplicity and the importance of collecting and storing only relevant data. A tenacious effort has been made to abide by these principles in the PFDS research. Like business executives, engineers have often been drowned in information, and the result may be manifested somewhat in the lingering reluctance highway engineers have for using computer-based information systems. Stacks of unused computer output have all too frequently been the visible evidence of a working MIS. The HRB Workshop on Structural Design of Asphalt Concrete Pavement Systems (Ref 37) recognized this situation as "data pollution" and concluded that it is a primary factor in abuse and misuse of data systems. Thus, this stage of PFDS development is perhaps the most important of all. The term "essential" has therefore been employed to convey the idea that only those factors absolutely necessary for an operating feedback data system are to be included. The decisions to exclude are difficult ones.

Relation to Other Functions

Before proceeding further, explicit recognition of the pavement design engineer's part in the overall highway system may serve to abate fears that disproportionate influence upon management is sought. While the serviceability of the highway system, as discussed herein, is the riding quality of the surface as expressed by serviceability index (SI), it is fully acknowledged that there is much more to the problem than the pavement system (or subsystem). Just as there are many types of highway maintenance efforts that have nothing to do with the pavement, so are there many considerations other than pavement structural adequacy that determine when a highway must be reconstructed. Figure 8 illustrates some elements of this puzzle. The highway system managers use all the pieces to arrive at a decision. It is not an objective herein to suggest the relative sizes of these pieces of the puzzle. All efforts are

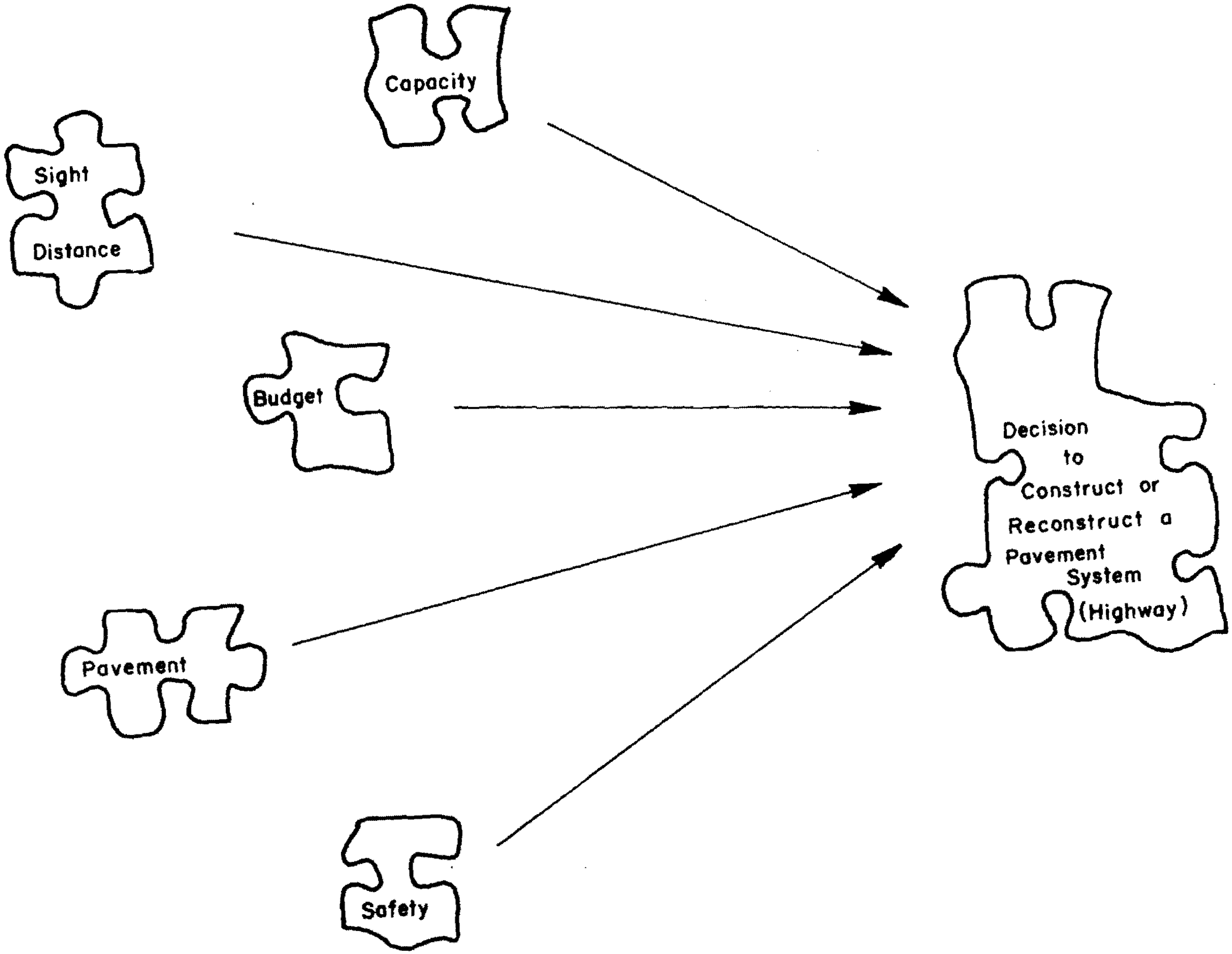

Fig 8. The highway management puzzle.

bent to furnishing the best possible pavement piece, one that is derived from logical analysis of the synergy of the pavement system components.

Early in this project, Haas (Ref 29) provided some introductory concepts relative to a pavement feedback data system that gave the problem an overall dimension. He showed that pavement performance, described by serviceability index (SI) was a function of at least three factors:

(1) Climate

(2) Traffic

(3) Pavement

Each of these factors is of course composed of several components or subfactors, some of which have been defined and some that probably have not yet been identified. Conceptually, the pavement performance situation can be represented as shown in Fig 9. The solid lines enclose factors and subfactors already recognized and identified as important while the dotted lines enclose factors not yet identified or adequately described.

Within the framework of Project 123, models and submodels have been defined to express, as well as the present state-of-the-art will allow, the activity within each pavement performance component. These models are derived from the vast reservoir of past research findings and adapted to conditions in Texas. The basic underlying foundation is the AASHO road test conducted in 1959-62 (Ref 8). This was followed by work at Texas Transportation Institute, the Texas Highway Department, and the Center for Highway Research (Refs 40 and 68). Superimposing the results of this work on the conceptual representation of the problem in Fig 9 we can now give names to the models, factors, and subfactors that make up our pavement design problem (see Fig 10).

The broken line boxes and vectors represent those models and subfactors, respectively, which are potentially present but not yet defined or even identified within the present context of the pavement design or performance problem. At this point in time, it can only be said that such factors are not a part of any current model. Continuing research and analysis will undoubtedly provide the identities in the future.

Future Additions

This PFDS research has precipitated a philosophy about pavement design in general and the PFDS in particular. Specifically and with some carefully

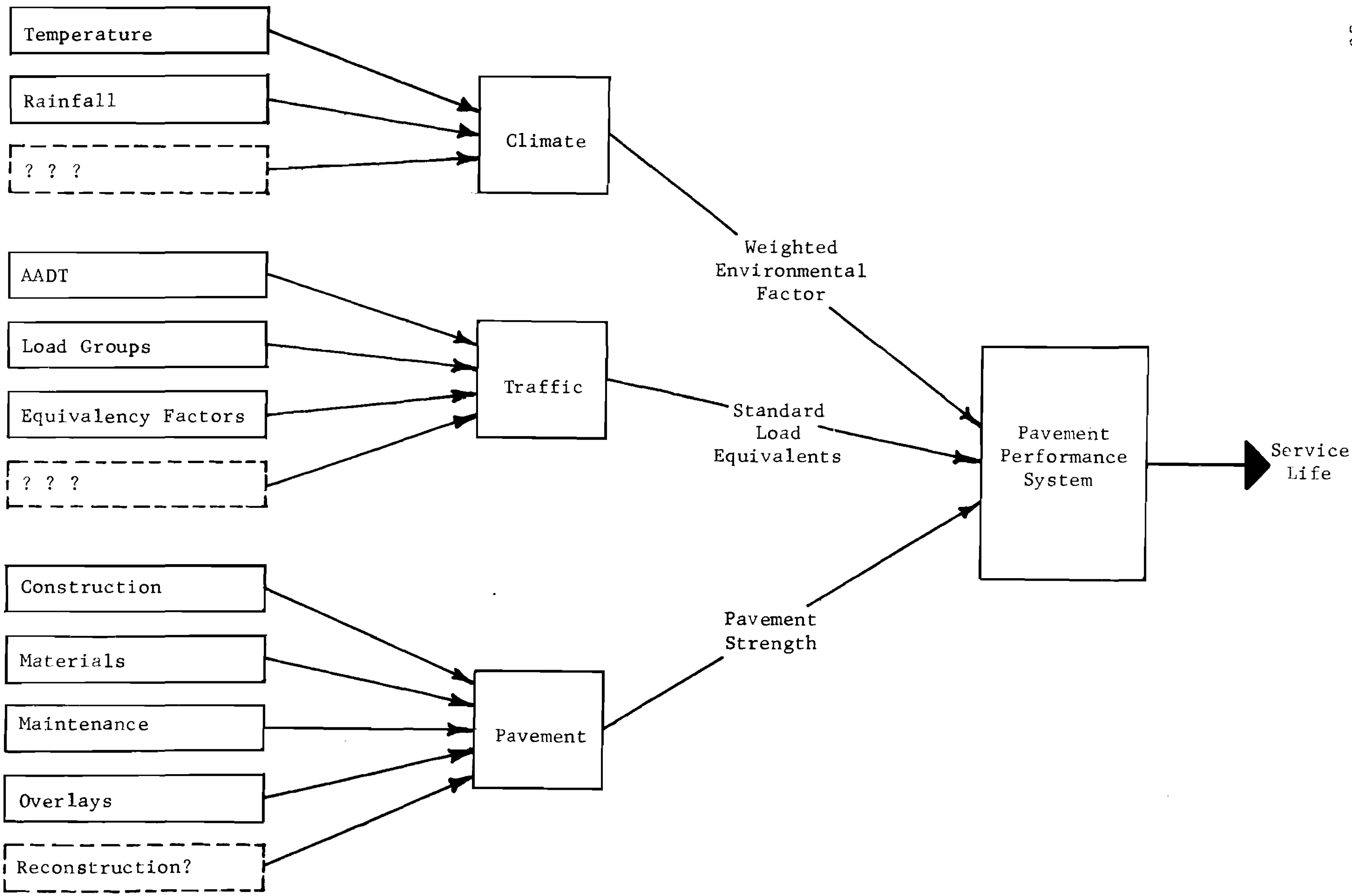

Fig 9. Components of pavement performance.

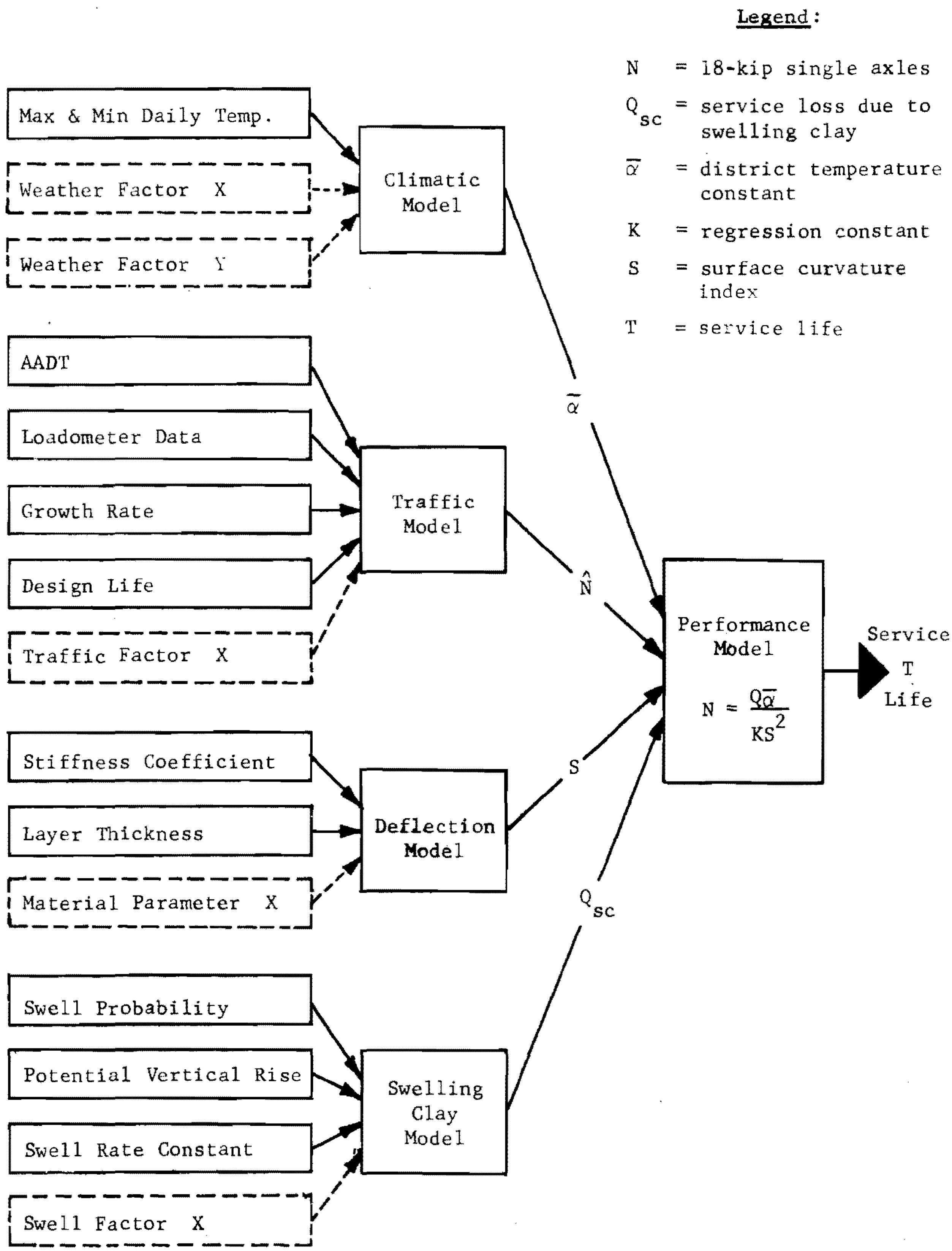

Fig 10. Flexible pavement system (FPS) design components.

selected exceptions, the variables or factors identified in the described process of model analysis are the only ones for which data will be collected and stored at the start. As pointed out in Chapter 2, the initial goal of PFDS is to provide fundamental research and management tools, later maturing into a design and more complete management complement. However, the first data inserted into PFDS will be used primarily for select management functions and to check the various design models. During this model checking process, it is important that results of other, even though directly related, research-in-progress not be inserted into the operational design methods until a distinct need for such is indicated by performance data. Even though some theoretical breakthroughs may be apparently concluded during this period of performance data collection and analysis, implementation should be effected only upon demonstration of an omission or change in performance prediction that call for a rational revision to the applicable model(s). Such a policy should help to prevent premature changes in design procedures and assure that modifications to models are made in the proper priority.

Some research in progress can be used to illustrate this point. M. Y. Shahin, a graduate student on Project 123 at The University of Texas, has developed distress prediction models for asphalt pavements that may soon allow refinement of design techniques to limit temperature cracking (Ref 70). This research is an attempt to quantify the solution to a problem which has plagued engineers for years. However theoretically sound it may now appear, no attempt should be made to introduce the models into operational design systems until they are verified by performance data. In many respects, operational design systems are also experimental processes and introduction of new factors and models before performance feedback is acquired simply enlarges the inference space and introduces new and unknown interactions. In other words, while the pavement engineer may have a reliable estimate of the direction in which he is headed or diverted, he cannot be sure of his starting point. If PFDS is allowed to function in conjunction with the operational pilot design system, a reliable origin can be established and the engineer may proceed more accurately toward his goal.

Current Design System

The current operational pilot design procedure for flexible pavements used by THD is designated FPS-11 and uses the inputs shown in Table 1. The

TABLE 1. VARIABLE INPUTS TO FPS-11 DESIGN PROGRAM AND SOURCE OF VALUES

Variables	How Values Obtained			
	Assign	Access	Compute	Measure
A. Basic Design Criteria				
1. Length of analysis period	X			
2. Minimum time to first overlay	X			
3. Minimum time between overlays	X			
4. Minimum serviceability index	X			
5. Design confidence level	X			
6. Interest rate	X			
B. Program Controls and Constraints				
1. Maximum funds available per square yard for initial construction	X			
2. Maximum total thickness of initial construction	X			
3. Maximum total thickness of all overlays	X			
C. Traffic Data				
1. ADT at beginning of analysis period		X		
2. ADT at end of analysis period		X		
3. One-direction cumulative 18-kip single axles during analysis period		X	X	
4. Average approach speed to overlay zone	X			X(1)
5. Average speed through overlay zone - overlay direction	X			X(1)
6. Average speed through overlay zone - non-overlay direction	X			X(1)
7. Percent ADT arriving each hour of construction		X		
8. Percent trucks in ADT		X		

(1) Elements of a potential special research project.

(Continued)

TABLE 1. (Continued)

Variables	Assign	Access	Compute	Measure
	How Values Obtained			
D. Environment and Subgrade				
1. District temperature constant	X		X(2)	
2. Swelling probability - clay subgrade				X
3. Potential vertical rise - clay subgrade	X(3)		X	X
4. Swelling rate constant - clay subgrade	X(3)			X
5. Subgrade stiffness coefficient			X	
E. Construction and Maintenance Data				
1. Initial serviceability index	X(3)			X
2. Serviceability index after overlaying	X(3)			X
3. Minimum overlay thickness	X			
4. Overlay construction time	X			
5. Asphalt concrete compacted density	X			
6. Asphalt concrete production rate	X			X
7. Width of each lane	X(3)	X(4)		
8. First year cost of routine maintenance	X(3)		X	X
9. Incremental increase in maintenance cost per year	X(3)	X	X	
F. Detour Design for Overlays				
1. Detour model used during overlay	X			
2. Total number of lanes of the facility		X		X(1)

(1) Elements of a potential special research project.

(2) Adjusted values may be computed from maximum and minimum daily temperatures for the specific locality.

(3) For design purposes.

(4) In Road Life file (RL-1) as plan quantity; see Chapter 6.

(Continued)

TABLE 1. (Continued)

Variables	Assign	Access	Compute	Measure
3. Number of lanes open in the overlay direction	X			X(1)
4. Number of lanes open in the non-overlay direction	X			X(1)
5. Distance traffic is slowed - overlay direction	X			X(1)
6. Distance traffic is slowed - non-overlay direction	X			X(1)
7. Detour distance around the overlay zone	X			X(1)
G. Existing Pavement and Proposed ACP				
1. SCI of existing pavement				X
2. Standard deviation of SCI			X	
3. Composite thickness of existing pavement		X		
4. In-place cost (compacted) C.Y. of proposed ACP	X			
5. Proposed ACP's salvage value as percent of original cost	X			
6. In-place value of existing pavement-compacted C.Y.	X			
7. Existing pavement's salvage value as percent of present value	X			
8. Level-up required for the first overlay	X			
9. Number of years existing pavement has been open to traffic		X		
H. Paving Material Information (All for each material to be considered in design.)				
1. Layer designation	X	X(4)		X

(1) Elements of a potential special research project.

(4) In Road Life file (RL-1) as plan quantity; see Chapter 6.

(Continued)

TABLE 1. (Continued)

Variables	How Values Obtained			
	Assign	Access	Compute	Measure
2. Name of material	X	X(4)		X
3. In-place cost - compacted C.Y.	X	X		X
4. Stiffness coefficient	X			X
5. Minimum allowable thickness	X			
6. Maximum allowable thickness	X			
7. Material salvage value as percent of original cost	X			

(4) In Road Life file (RL-1) as plan quantity; see Chapter 6.

background and explanation of this computerized design system are contained in a report entitled "A Systems Approach Applied to Pavement Design and Research" (Ref 40). Also shown is the probable source of the data values. The following definitions regarding how values are obtained apply:

"Assign" means that values are selected by the designer based on engineering judgment or as reasonable program constraints to prevent unreasonable design results.

"Access" means that values are obtained from existing data sources such as the THD D-10, D-8, or D-18 data files.

"Compute" means that values are obtained from computation upon raw data either accessed or measured.

"Measure" means that field sampling of data values is or will be necessary.

It will be noted on the second page of the table that certain variables (marked by note 2) are shown to have values "assigned" as well as "measured." This situation occurs whenever insufficient performance (measured) data is available, or whenever two different times in the design, construction and performance process are inherent in the particular variable values. An example of this is initial serviceability index, 1 in group E. A design value, which represents the mean value for new flexible pavements in Texas, will be assigned. When the pavement is constructed, the actual serviceability index will be measured and compared to the design value. The resulting difference is a measure of the variability in construction practices and techniques.

Future Research Projects

Under groups C and F of Table 1, nine variables are designated as potential special research items for measurement (note 1). All of these items are used to compute the "user-costs" incurred during overlay projects at one or more times in the future use of the particular highway system (Ref 67). The user-cost models tend to oversimplify a very complex situation and this whole matter could easily use a separate research effort. Instead of collecting data on every detour used in practice, a well-designed experiment will probably yield more discernible results in a more efficient manner.

The note 4 refers to the Road Life file (RL-1) of D-10. This file will be discussed in detail in Chapter 6; however, at this point, it is sufficient to recognize that the indicated variables are currently included in an existing file and the data should serve adequately for future reliability and stochastic research within Project 123.

Essential Factors for PFDS

The basis for variables to be included in PFDS must necessarily come from FPS-11; input variables to that program are the basic essential factors for PFDS. However, these factors have both a time and space dimension that must also be sampled. All factors will exhibit variability as we progress down a roadway; for example, as-built surface thickness will vary around some mean value, possibly the design or plan quantity. Other factors will vary with time; for example, serviceability index will tend to decline with time from some high initial value. The handling of this situation will be evident in the discussion of the PFDS files later in the chapter. The acquisition of time-dependent data values is also discussed in Chapters 4 and 8.

Specific recognition of the time and space dimensions of the factors, and the formation of a plan to sample accordingly, provides the raw data needed to further the probabilistic and reliability concepts now being actively pursued in the Flexible Pavement System (FPS) (Refs 13 and 15). Darter (Ref 14) considers three types of variability in his reliability concepts

(1) variability within a project such as pavement thickness, material strength, etc.;

(2) variability between design (plan) quantities and as-built values; and

(3) variability due to lack-of-fit of design models in FPS-11.

Recognition of these sources of variation serves as an important second development parameter for PFDS, specifically, the need to be adequately responsive to the active research in reliability and stochastic applications in FPS.

Just as important in any sampling plan is the determination of methods or techniques for taking data measurements. The methods must be standardized in so far as possible so that direct comparisons are valid. For example, the serviceability index of all highways must be determined by devices all calibrated to a common reference device. This is done in the Texas method (see Ref 85). Another example is the Texas Triaxial Class, a material property that is fundamental to a standard design procedure used in Texas (Ref 74). Because the cost of this test is high, the triaxial class is often determined from one of several possible "shortcut" techniques. Therefore, the record must specify the method which was actually used. This is discussed in more detail in Chapter 7.

Undefined Influences Upon Performance

Before proceeding to definition of the proposed PFDS files and essential factors, it will be helpful to examine again the typical serviceability/performance diagram shown in Fig 6 of Chapter 4. Each of the abrupt increases in the performance index values represents an event that should be recorded to permit complete subsequent analysis of the pavement system. Seal coats and overlays are certainly two significant events to record. Beyond those two, however, problems are promptly faced. What maintenance work affects the serviceability/performance life to an extent that it should be recorded for analysis? How much cracking must exist before sealing becomes significant? Cracking influence upon present serviceability index (SI) was quantified in the AASHO Road Test equations (Ref 8) but no satisfactory method of relating distress to performance (failure) has been derived. When sufficient data are collected, researchers will be in a position to ascertain this relationship more readily. The potentials of PFDS are described in Chapter 9.

The same thing can be said for other types of distress upon which important maintenance is performed. The Texas Highway Department Maintenance Manual (Ref 75) recognizes five types of asphaltic concrete distress and prescribes repair and prevention methods. Most of these maintenance and repair efforts will be specifically identified and pursued as individual job numbers in the regular THD accounting system, as discussed in Chapter 4, and the basic parameters of cost and general description can be easily included in PFDS. However, a distress survey something like that now being proposed in a new research study (Ref 57) is needed. The findings should be implemented as a future revision to the PFDS files and essential factors. In summary, it is fully acknowledged that maintenance efforts are very important in pavement performance and life, but until the significant factors can be explicitly defined in the FPS context, detailed distress and maintenance data collection and storage are premature. During the interim, maintenance costs can serve as a substitute parameter to measure distress.

The PFDS Files and Factors

Definition of the PFDS files and essential factors is now appropriate. A harsh interpretation of the PFDS objectives suggests that only the inputs to the FPS-11 design method should be included. However, one exception may be in order. Since Triaxial Class is a fundamental parameter in an existing manual design method (Ref 74), its inclusion in PFDS may be warranted to satisfy essential near-term design needs until FPS becomes a universal THD method. Thus it has been included in the proposed structural file.

Table 2 provides a complete listing of proposed files and essential factors. Six logical groupings of factors have been identified, each group to correspond to a master file in PFDS. Each master file may have one or more "trailer" files to provide additional detailed data as necessary. This concept is discussed in detail in Chapter 8. In addition, each file will contain certain time and locational data entries to positively identify the data by sample phase (design, as-built, or subsequent), date, and specific highway location. These features are also discussed in Chapter 8.

The following explanation of file features in Table 2 is appropriate:

(1) Structural File: contains the factors that uniquely describe the pavement structure. The file will have variable length records depending on number of layers and future overlays (events). The following additional comments are applicable:

   (a) The sample phase for this file will always be design or as-built, i.e., the value used in design or the as-built feature/value.

   (b) "Design comments" allow the insertion of the reason(s) for a design strategy or a subsequent event (overlay or seal coat).

(2) Environment File: contains the essential environmental factors used by FPS-11 to estimate effects upon performance. The first is readily available as a computed constant at the present time. However, its value is derived from minimum and maximum daily temperatures for the individual district headquarters. More precise values can be readily computed for the specific district area where a given project is located by acquiring the National Weather Service (NWS) records for the nearest NWS temperature station. There are some 1,000 such stations in Texas and a single magnetic tape containing these data for 22 years (1948-1970) can be obtained for a nominal fee from the Austin office of the Texas Water Development Board. Once computed for several sub-areas within a district, such a temperature constant based on 22 years of data should require little if any future adjustment. This could be a one-time effort and eliminate all future temperature data collection (accessing).

TABLE 2. PFDS FILES AND ESSENTIAL FACTORS

	Sample Phase			Data Source
	Design	As-built	Subsequent	If Other Than PFDS
A. Structural (Fields 1-5 for each layer including subgrade.)				
1. Layer designation and code	X	X		Final plan quantities in D-10 Road Life (RL-1) file.
2. Material name	X	X		" " "
3. Layer thickness	X	X		" " "
4. Stiffness coefficient	X	X	X	
*5. Triaxial class	X			
6. Design comments	X			Coded comments in D-10 RL-1 file.
7. Lane width	X	X		Final plan values in D-10 RL-1 file; inventory values in Road Inventory (RI-2) file.
(Fields 8-11 for each subsequent event until complete reconstruction.)				
8. Event (type work)	X	X		Plan values in RL-1 file.
9. Date	X	X		Same as for factor 6.
10. Layer thickness	X	X		Same as for factor 8.
11. Design comments	X			Same as for factor 6.
B. Environment				
1. District (local temperature constant	X		X	National Weather Service
2. Subgrade swelling probability	X	X(1)	X	
3. Subgrade potential vertical rise	X	X(1)	X	
4. Subgrade swelling rate constant	X	X(1)	X	

* Exclude from surface layer data field.

(1) Opinion of construction engineer.

(Continued)

TABLE 2. (Continued)

	Sample Phase Design	As-built	Subsequent	Data Source If Other Than PFDS
C. Performance				
1. Surface Curvature Index	X	X	X	
2. Serviceability Index	X	X	X	
3. Minimum Serviceability Index	X		X	
4. Design Confidence level	X		X	
D. Traffic				
1. ADT-initial	X	X	X	D-10 Traffic Log
2. ADT-final	X	X	X	D-10 Traffic Log
3. 18 KSA Equivalent	X	X	X	D-10 Traffic Log
E. Costs				
1. Initial Construction $/sy	X	X		
2. Overlay Construction $/sy	X	X		
3. Special Maintenance $/sy	X	X		
F. Constraints	(Design values only)			
1. County				
2. Highway				
3. IPE (Investigation Planning Expense Number)				
4. Length of analysis period				
5. Minimum time to first overlay				
6. Minimum time between overlays				
7. Interest rate				
8. Problem type				
9. Maximum funds available per S.Y. for initial construction				

(Continued)

TABLE 2. (Continued)

	Sample Phase			Data Source
	Design	As-built	Subsequent	If Other Than PFDS
10. Maximum total thickness of initial construction				
11. Maximum total thickness of all overlays				
12. Average approach speed to overlay zone				
13. Average speed through overlay zone - overlay direction				
14. Average speed through overlay zone - non-overlay direction				
15. Percent ADT arriving each hour of construction				
16. Percent trucks in ADT				
17. Minimum overlay thickness				
18. Overlay construction time				
19. Asphalt concrete compacted density				
20. Asphalt concrete production rate				
21. First year cost of routine maintenance				
22. Incremental increase in maintenance cost/year				
23. Detour model				
24. Total number of lanes				
25. Number lanes open in overlay direction				
26. Number lanes open in non-overlay direction				
27. Distance traffic is slowed - overlay direction				
28. Distance traffic is slowed - non-overlay direction				
29. Detour distance around overlay zone				
*30. Composite thickness of existing pavement				
*31. In-place cost/compacted C.Y. of proposed ACP				
*32. Proposed ACP's salvage value as percent of original cost				
*33. In-place value of existing pavement/compacted C.Y.				
*34. Existing pavement salvage value as percent of present value				
*35. Level-up required for the first overlay				
*36. Number years existing pavement has been open to traffic				
(Fields 37-44 for each material considered in design)				
37. Layer designation number				

* For ACP overlays only.

(Continued)

TABLE 2. (Continued)

	Sample Phase			Data Source
	Design	As-built	Subsequent	If Other Than PFDS
38. Letter code of material				
39. Name of material				
40. In-place cost/compacted C.Y.				
41. Stiffness coefficient				
42. Minimum allowable thickness in initial construction				
43. Maximum allowable thickness in initial construction				
44. Material's salvage value as percent of original cost				

It may also be pertinent to note that other climatological data may be obtained just as easily. Rainfall, wind, and evaporation are three such factors that could eventually become inputs to a new environment effects submodel within the pavement design system.

The other three factors in the environmental file all contribute to the swelling clay model that estimates performance degradation due to subgrade movements. These factors are unique to FPS-11 and must be acquired and contained in PFDS.

(3) Performance File: contains those factors essential to describing the pavement performance. The first two factors are self-explanatory; they are fundamental to any measure of performance. Minimum serviceability index and design confidence level are shown to fall in subsequent data phases, or sometime during the life of the pavement. This possibility could arise only if these design parameters are changed in a subsequent overlay design.

(4) Traffic File: contains the essential traffic data for design. Note that all of these are shown to exist in the THD D-10 traffic file; therefore, no data storage in PFDS is necessary. This file will consist only of a computer instruction to access the D-10 Traffic File by its proper name.

(5) Costs File: these three factors are the only ones for which as-built or subsequent data collection appears appropriate.

(6) Constraints File: this file will be a simple listing of all of the remaining FPS-11 inputs not already a part of another file. These data factors are the program constraints and judgment values of the designer. They have a design value only and will be used to reconstruct the design strategy at a later date.

Management Factors

The management potential of the proposed PFDS is somewhat difficult to predict, but the one most important management factor is clearly serviceability index. Different factor combinations will undoubtedly be used by each District Engineer to satisfy his own particular needs. Service life estimates derived from design and as-built data should serve adequately for construction programming and budgeting purposes.

One other management factor not included in PFDS merits mention here. The Skid Resistance Factor is a measure of increasing importance in the interest of highway safety. It indicates when some type of maintenance action or surface treatment is needed to improve skid resistance, and D-8R has begun an extensive program of testing and recording this information. Like D-10 files, this file will be accessible in MARK IV by its proper name as needed; there is no apparent need to store skid data in PFDS files.

Special Research Files

Most of the special research projects discussed earlier will involve acquisition and analysis of varying quantities of data. It may be advantageous to utilize computer processing of such data and consideration should be given to definition of temporary files within PFDS to serve the research project. MARK IV makes creation of temporary and working files relatively simple and this capability should be exploited fully.

CHAPTER 6. EXISTING DATA FILES AND SOURCES

Scope of Existing Files

With the essential data factors for PFDS identified, it is now logical to examine the existing data assets of THD to ascertain how many factors are already included in current files. Over the years, the Texas Highway Department has acquired a wealth of highway data and developed a comprehensive set of files for many purposes. When the computer came along, the Planning Survey Division (D-10), along with the Automation Division (D-19), promptly set about automating the data handling procedures so that today, practically all of the D-10 files have some form of computer handling. J. E. Wright, THD D-10 Division Head, announced the Texas plan for a state-wide data base at the Highway Research Board symposium on automation in August 1971 (Ref 91). Over three years before, D-10 had completed a thorough system analysis and published a two volume report (Ref 78). By December 1971, D-10 was operating 10 data files consisting of over a half million records and another 350,000 accident records were being processed each year.

D-10 Data File Relevancy

An early PFDS research objective was to thoroughly examine these D-10 files and identify data needed for the pavement design and research process. This proved very profitable as was indicated in the preceding chapter. Many of the essential factors are already in one or another of the D-10 files and the problem then becomes only a matter of how to access such files and fields. This problem appears well on the way to solution with the acquisition of the MARK IV file handling system and the potential for a universal record key discussed in Chapter 4. The remaining obstacles are discussed in Chapter 8.

Although identification of the specific essential factors that could be accessed from D-10 files was made in the preceding chapter, it is doubtful that the scope is adequately defined without a look at the files and their contents. Two D-10 files are highly relevant to PFDS:

(1) Traffic Log - with approximately 66,500 records - and

(2) Road Life (RL-1) - with approximately 161,000 records.

The Traffic Log. Other than the basic highway identification information, there are 31 different fields of data in this file. Ten fields are Annual Average Daily Traffic (AADT) for the preceding 10 years. This information is derived from both automatic and manual counting stations throughout the state. The remaining data items are essentially for future design functions and are derived from loadometer studies as well as computation. Included in this group are traffic growth factor, 18 kip single axles, and percent trucks. All of the data items used in a standard THD pavement design procedure (Ref 74) are contained in this file, and are made available to other divisions and districts upon request. Data records are coded with the beginning and ending milepoints, so the specific segment of a given control section can be readily pinpointed. In summary, this file is already used as an important information source for the pavement engineer and will continue to be important (see coding form and sample output, Appendix C).

The Road Life File (RL-1). This file is probably the most relevant, comprehensive, and consolidated source of information that the THD pavement engineer can find anywhere in the Department. Furthermore, examination of the manual records from which the computer file is derived will show that they have been diligently maintained. This would suggest a high degree of data accuracy.

The system analysis staff report (Ref 78) states that the RL-1 records are "in detail as to type and design of construction and the dollar investment by construction components." The following discussion will attempt to summarize how comprehensive that statement is as applied to the pavement design function.

The manual records consist of the penciled form RI-2, "Log Record of Project Construction and Retirements." A typical record was selected at random and is shown in Fig 11. Note that the control section information is prominently displayed in the upper right corner; each control section is a separate record. The local features describing the termini of the control section are given on the top left. The next significant feature is the job number, the fourth column from the left. This record depicts every item of work performed on this segment of roadway since 1927. Each of the parallel

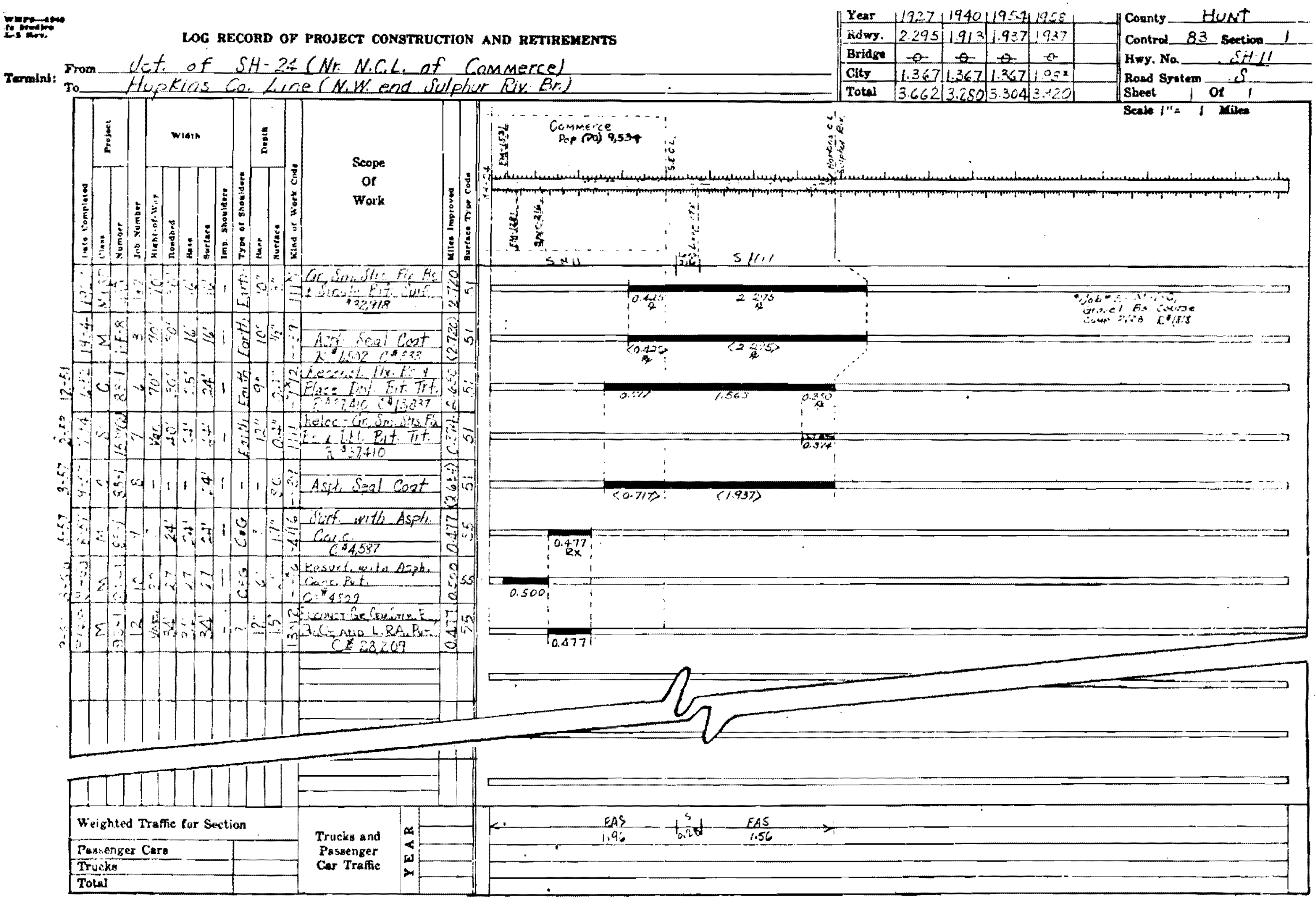

Fig 11. Typical road life record.

bars upon which shading and notations have been made represents the same roadway but shows only that work done on the designated job number. There have been 12 job numbers but only 10 are accounted for here. The other two apparently had no effect upon the pavement. A number of codes are used but note the numerical data on depth, width, and type of surface, base, and shoulders.

The automated version of this data record is equally impressive. Using rather extensive coding, the records can contain up to 132 different data items per segment of roadway as defined by control section and job number. The following is a selected list from the RL-1 file that are most relevant to PFDS (Ref 77) (see Road Life coding form, Appendix D):

(1) Surface type - 13 different codes from bladed earth to ACP overlaid concrete.

(2) Type of work - 44 different codes used in combinations to allow designations from simple grading to complete reconstruction.

(3) Cross Section of Surface - width is coded to nearest foot; thicknesses are coded to nearest tenth of one inch.

(4) Cross Section of Base - coding tolerances same as for surface.

(5) Shoulder Type - 10 different codes from no shoulders to curb and gutters.

(6) Shoulder Width - coded to nearest foot.

(7) Type of Treatment (Surface) - 15 codes to designate the range from none to hot plant mix asphaltic concrete.

(8) Aggregate Distribution - coded to specify number of square yards covered by one cubic yard of surface aggregate.

(9) Base Material - 9 different codes - none to brick.

(10) Method of Base Stabilization - 8 codes to designate range from none to lime, asphalt, and cement.

(11) Subgrade Material - 3 codes: earth, flexible base or foundation course, and select material.

(12) Subgrade Stabilization Method - 4 codes: none, cement, asphalt or lime.

(13) Subgrade Width - coded to nearest foot.

(14) Subgrade Depth - actually means subbase and is coded to nearest inch.

From the above, it is obvious that the cross section of the existing pavement structure (plan quantities) can be easily developed. It must also be noted that while concrete pavement surface was omitted from the above discussion, there is comparable information in the file for that material as well (see data fields 21-24, Appendix D).

In addition to the above pavement structure data, the file contains interesting information on the reason and method of pavement retirement, along with the length, date, and cost of the retired pavement. The term "retirement" as used herein means removal of the pavement from service for one or more of several reasons. For example, the pavement may have failed or become obsolete. RL-1 allows 28 different coded reasons for retirement. Methods of retirement have 51 different coding options varying from simple resurfacing to reconstruction along new line and new grades. This type of information is analogous to the design comments specified as an essential factor in the Structural File of PFDS.

The net potential of the RL-1 file is to provide data for all but two of the essential factors in the PFDS Structural File as indicated in Table 2. This data could initially suffice for the design sample phase until a reconstruction design is prepared using FPS-11 or its successor program. However, one significant problem exists in regard to this data file. Specifically, data records are set up for each job number, but the physical limits of the job number are not contained in the file. This means that there is no direct measure of the beginning and ending points referenced to some common base such as milepoint or beginning of control section. As previously pointed out, the traffic log contains these essential data.

To be of full value to PFDS, this type of locational parameter must be incorporated in the file. D-10 has given this matter consideration in the past and decided that insertion of the milepoint data for all previously accomplished projects was simply too large a task to be practical. It should be emphasized that milepoints for each job number could be derived from the manual RL-1 records; each job number is defined on the final plans with stationing referenced to some known point such as beginning or ending of control section, geographical feature, or political boundary.

It is suggested that a limited effort could provide a reasonable solution to this problem. D-10 has already reserved columns in the RL-1 file record format for beginning and ending milepoints. Therefore, no format changes are necessary and a coordinated effort between D-8 and D-10 could be undertaken to

(1) begin coding beginning and ending milepoints for each new job number being entered in RL-1, and

(2) select on a case by case basis certain previously accomplished major construction/reconstruction or overlay job numbers to compute the milepoints (or stationing) from penciled RL-1 records and enter in the automated file.

For the immediate future, the above two steps can probably be done manually as needed with acceptable efficiency. When MARK IV is fully operational with a random access capability, the data fields in RI-2 can be accessed to yield certain milepoint data upon which calculations for RL-1 data can be automatically performed. For example, where control section milepoints are already entered in the road inventory (RI-2) files, a processing program could be written to take the job number stationing from RL-1 input, access milepoint from RI-2, compute job number milepoint limits and store the result in the appropriate record files in RL-1. In any event, the existing deficiency of detailed locational data for job number in RL-1 can conceivably be eliminated on a phased basis with little total increase in existing workloads. The amount of extra work is acknowledged to be an important consideration and should be carefully weighed in any adopted course of action.

Another limitation of the RL-1 file is the existing provision for only two subsurface layers. Data describing the surface and base layers appear completely adequate and the data entered in the subgrade field (field 28, Appendix D) are descriptive of the subbase. When more than one subbase layer is used in construction, all are combined as one composite layer for recording purposes. In some instances, two markedly different materials could be used for subbase layers and the data entered may not be sufficiently descriptive for both layers. On the other hand, a continuously reinforced concrete pavement (CRCP) overlay of an existing jointed portland cement concrete (PCC) pavement with a bond breaker may be considered as different layers. D-8 and D-10 should evaluate this restriction and determine whether there is sufficient merit in establishing more data fields to accomodate additional subbase layers.

Other Data Files

The automated data file Road Inventory (RI-2) previously referred to could be relevant to pavement design functions and is certainly an excellent management tool. RI-2 contains broad summaries of the structural composition besides highway grades, curves, and administrative information. In some respects, it is representative of the other more detailed files of traffic, structure, and geometrics. It has the disadvantage of being a sequential tape file as is RL-1 and random access of the data records is impossible (see Appendix E).

For environmental information, the National Weather Service (NWS) possesses records that are readily accessed by computer to yield a wide variety of data factors. The ones essential to PFDS are maximum and minimum daily temperatures, from which the district temperature constant is derived. As discussed in Chapter 5, this data is readily available for the past 22 years for all 1,000 NWS temperature stations in Texas. In addition, the following data are available from the same source for the period 1948-1970:

(1) daily and monthly precipitation for 1,400 stations,
(2) daily and monthly pan evaporation for 600 stations, and
(3) daily and monthly wind movement for 300 stations.

The acquisition of only the temperature data tapes is suggested for the present. These should be used in a special research project to evaluate whether temperature constants vary sufficiently within the district to warrant use of "localized" values. If not, there seems little point in transferring some 16 million temperature readings to a computerized direct access storage device, even though it would be a simple matter to do so. Frank Scrivner, Texas Transportation Institute, (Ref 66) computed the district temperature constants now being used in FPS-11 from 10 years of data, and appreciable departure from such values seems highly unlikely, even with over twice the data. Furthermore, Ramesh Kher et al found in Project 123 sensitivity studies that the factor is only a moderate influence upon optimal design strategy (Ref 47). Such a special research effort could also conclude whether future acquisition and analysis of temperature data are warranted and if so, in what summary form they should be stored.

In the area of manual data files, the scope is simply too large to even summarize. Besides the vast files of the Equipment and Procurement Division (D-4), the individual districts possess a wealth of information from the construction control process. These records may become important in the development of sampling processes since there may already exist adequate procedures for _acquiring_ the data. Sampling may then reduce to a problem of selective _reporting_ via remote computer terminals according to some specified format. This is discussed further in Chapters 7 and 8.

Summary

The D-10 Traffic Log and Road Life (RL-1) file are by far the most important records of immediate interest. Hopefully, THD acquisition of MARK IV coupled with redefinition of these files with compatible record control keys will make the data immediately available to the pavement designer and manager. It is emphasized that these records appear to be reliable and complete and it is suggested that they be used to the maximum extent. Furthermore, where changes and/or additions are desired to some data fields, a first recourse should be to work through existing procedures to obtain satisfaction. Just as with the record control key, the emphasis should be on making existing mechanisms work unless clear-cut deficiencies dictate otherwise. The great value of such efforts can be seen from the milepoint deficiency in the RL-1 file; the vast and relevant data elements therein can be had for relatively small additional effort.

CHAPTER 7. DATA SAMPLING

Sampling Concepts

After the fundamental decision is made as to what data to collect, the next step is recognition of the sources of data. Except for the assigned and computed data values, all other data must be obtained from either accessing other data files or sources, or measuring the factors in the field. Either way, the pavement engineer must be confident that the numbers he gets are valid representations of the pavement design problem. This means that a data sampling plan or philosophy must be developed and applied to both parts of the problem. For data to be accessed, the sampling plan and procedures must be checked; for data to be collected, the plan and procedures must be developed.

Sampling Techniques

Consultation with statisticians reveals that the best practical sampling approach for this type of data system is a systematic random sample on a stratified basis. Loosely translated, this simply means that the highway from which data is to be measured is first separated into strata or levels that are fairly homogeneous within themselves. Then each strata is sampled by beginning at a random point and taking sample values at regular intervals throughout the strata. As an example, serviceability index (SI) may be our particular pavement factor. First we select a segment of highway that has the same type surface and was probably constructed by the same contractor at the same time (same contract); this is our stratum. Then we pick a random starting point and measure and record an SI value every 2,000 feet throughout our selected segment.

Two significant features of the stratified, systematic random sampling method should be explicitly recognized (Ref 10, pp 206-230):

(1) There should be no cyclic effects within a stratum. For example, seasonal changes are a cyclic effect upon climate and any factor dependent upon climatic conditions must be sampled so that appropriate representation of each season is obtained. In some areas

of Texas, the surface curvature index (SCI) is directly dependent on time of year. SCI readings should then be taken within each season.

(2) The variance tends to be overestimated, i.e., larger than the true variance. In general, this means that probabilistic design values derived from such data should be conservative, i.e., there should be a kind of safety factor.

The same sampling procedure is applicable to time variable data as well. After selecting the strata of the factor, each stratum is sampled at a regular interval of time, i.e., each year. The same example of SI may serve here; SI values will be taken each year at some particular time.

This time interval of sampling will be, of course, dependent upon capability to take the sample. Presently available THD resources may not permit annual sampling. For example, THD has four Mays Road Meters for taking SI readings. Simple arithmetic shows that to cover the 70,000 miles of state system in one year, each unit must cover about 70 miles per day. This kind of schedule may not be possible for several reasons and the plans would have to be changed to fit equipment, or vice versa. However, implementation of PFDS will be a phased procedure and will not require immediate sampling on all highways. Therefore, sampling capability can be matched to needs on a progressive basis.

Stratum Equals Job Number

In Chapter 4, a record control key was defined to include the job number of the particular work being performed. The definition of job number shows that it is variable in length and scope of work but is generally a consistent type of pavement work, i.e., maintenance, overlay, reconstruction, or construction. In general, it will all be done by the same work force (THD work force or contractor) at one given period of time. If it involves reconstruction or construction of a new pavement, the same design thickness and materials will probably be used throughout the length of the job. There are a number of other variations such as number and type of superstructures, but these generally have no bearing on pavement construction. The net effect is that job number as a unit of work measure becomes a natural and practical homogeneous stratum for sampling purposes as far as pavement structure is concerned. This was a consideration in the selection of job number as an element in the record control key and the result is a maximum benefit from a consistent method of highway identification in the existing Texas Highway Department records system.

There will undoubtedly be instances where distinct breaks in pavement characteristics or design will occur within the length specified by a single job number. For this reason, a decimal position has been allotted to the job number to permit up to nine subdivisions of a given project (job number). This is emphasized to apply to such situations as a change in design thickness of pavement, not to stochastic variability expected within a project.

Sampling as a Function of Objective

Sampling must be guided by the purpose for which the data will ultimately be used. PFDS is expected to contain data for

(1) management,
(2) design, and
(3) research.

For management, a single representative data value may adequately represent a factor in a control section and job number segment of roadway. Design will probably require more data values to permit selection of a critical value upon which to base a design. The term "critical" is used here in the statistical sense and refers to that value which gives the engineer a specific level of confidence that his design will be adequate. Research undoubtedly needs more detailed information than either of the other two objectives. In the beginning, the essential factors are probably a common denominator for all three objectives and were selected accordingly for PFDS. This will change with time; as design models prove adequate for a situation, they may be moved from the research to the design realm. Management factors will probably always be highly summarized values of a few basic factors.

Sampling as a Function of Resources

Each essential factor must be looked at individually to establish its desired sampling density. Now another consideration comes into focus, namely, the availability of THD personnel and equipment resources. This was briefly introduced in an earlier discussion of serviceability index sampling. Equipment available will be a fundamental limitation in many cases. In other situations, the number of qualified personnel available will govern. This will be influenced greatly by the policies and interests of the particular District Engineer. In fact, the District Engineer may determine the success or failure of the data system in his own district. Therefore, it is especially important that he be given all the facts and potential in the most concise, accurate, and direct manner.

Standardized Measuring Apparatus and Techniques

In order that data from district to district may be directly comparable, it is important that the measuring apparatus and techniques be standardized. For example, it would be undesirable for one district to use a Mays Road Meter to sample serviceability index while another uses a rating panel. Similarly, the techniques for arriving at triaxial class should be the same for all districts. In some cases, this is going to require a great deal of coordination. However, much has already been done. A method for calibrating the various Mays Road Meters has been developed and is being refined now (Ref 85). For many years, the quality control tests for materials have been standardized and codified. This is well illustrated by the job control and progress record testing required in the Texas Highway Department by the construction manual (Ref 72). Figures 12 and 13 are taken from that manual and show the guide test schedule for asphaltic concrete pavements, surface treatments, and the base, subbase, and embankment materials. It will also be noted that the concept of systematic sampling discussed earlier in this chapter has been followed in the illustrated sampling guides. In summary, it appears that most of the established sampling methods will probably suffice for PFDS and the problem is reduced to standardizing tests for those essential factors that are new to the design engineer and were first introduced to the pavement design field by the flexible pavement system (FPS). Such factors number only six:

(1) serviceability index,
(2) stiffness coefficient,
(3) subgrade swelling probability,
(4) subgrade potential vertical rise,
(5) subgrade swelling rate constant, and
(6) surface curvature index.

EMBANKMENTS, SUBBASES, AND BASE COURSES

	Test For	Test Number	Job Control Tests: Location or Time of Sampling	Job Control Tests: Frequency of Sampling	Progress Record Tests: Location or Time of Sampling	Progress Record Tests: Frequency of Sampling	Final Record Tests	Remarks
[illegible]	Compaction	Tex-114-E	As Designated by The Engineer *	Each 3,000 C.Y.	Same as Job Control	Each 100,000 C.Y. Min. 3	Progress Record Tests Are Also Final Record Tests	
UNTREATED SUBBASE AND BASE COURSES	Gradation	Tex-110-E	During Stockpiling Oprs., from Stockpile, or from Windrow *	Each 1,200 C.Y. or 1,600 Tons	Same as Job Control	1 Out of 20 Job Control Tests Min. 3	1 Per Travel-Way Per Mile Min. 3-Max. 10 (B)	Final Record Tests For Informational Purposes Only
	Liquid Limit	Tex-104-E	During Stockpiling Oprs., from Stockpile, or from Windrow *	Each 1,200 C.Y. or 1,600 Tons	Same as Job Control	1 Out of 20 Job Control Tests Min. 3	1 Per Travel-Way Per Mile Min. 3-Max. 10 (B)	Final Record Tests For Informational Purposes Only
	Plasticity Index	Tex-106-E	During Stockpiling Oprs., from Stockpile, or from Windrow *	Each 1,200 C.Y. or 1,600 Tons	Same as Job Control	1 Out of 20 Job Control Tests Min. 3	1 Per Travel-Way Per Mile Min. 3-Max. 10 (B)	Final Record Tests For Informational Purposes Only
	Wet Ball Mill	Tex-116-E	During Stockpiling Oprs., from Stockpile, or from Windrow *	Each Normal Day of Production				
	Triaxial	Tex-117-E(II)	During Stockpiling Oprs., from Stockpile, or from Windrow *	Each 12,000 C.Y. or 16,000 Tons				Not a Field Laboratory Function
	Compaction	Tex-114-E	As Designated by The Engineer	Each 2,000 Lin. Ft. Per Course Per Travel-Way (B)	Same as Job Control	1 Out of 20 Job Control Tests Min. 3 (C)	Progress Record Tests Are Also Final Record Tests	
	Thickness		As Designated by The Engineer	1 Depth Per 2,000 Lin. Ft. Per Course Per Travel-Way (B)			1 Total Depth Per Travel-Way Per Mile Min. 3-Max. 10 (B)	
TREATED SUBBASE AND BASE COURSES — BASE MATERIAL	As Shown Above For Untreated Base							
LIME	Compliance With Item 264 "Hydr. Lime & Lime Slurry"	Tex-600-J	Sampled, Tested, and Approved by D-9					
CEMENT	Compliance With The Std. Specifications & Spl. Provisions	ASTM C-150	Railroad Car, Truck, or Cement Bins	Each 2,000 Bbls. (May Be A Composite Sample) For Each Type or Brand	Same as Job Control	Witness Sampling At Least Once		Each Brand and Each Type To Be Sampled and Tested Separately
ASPHALT	Compliance With Item 300 "Asphalts, Oils and Emulsions"	Tex-500-C, Etc.	Sampled, Tested, and Approved by D-9					
COMPLETE MIXTURE	Gradation (A)	Tex-110-E & Spec's.	Roadway; After Pulverization	Each 1,200 C.Y. or 1,600 Tons	Same as Job Control	1 Out of 20 Job Control Tests Min. 3 (C)		(A) Where Required To Control Degree of Pulverization
	Compaction	Tex-114-E	As Designated by The Engineer	Each 2,000 Lin. Ft. Per Course Per Travel-Way (B)	Same as Job Control	1 Out of 20 Job Control Tests Min. 3 (C)	Progress Record Tests Are Also Final Record Tests	
	Thickness		As Designated by The Engineer	1 Depth Per 2,000 Lin. Ft. Per Course Per Travel-Way (B)			1 Total Depth Per Travel-Way Per Mile Min. 3-Max. 10 (B)	

* District Engineer Will Select Any One of These Three (3) Locations or Any Combinations Thereof With The Provision That A Minimum of 25% of Tests Will Be Sampled from The Windrow For Gradation, Plasticity Index, and Liquid Limit Only.

(C) Min. 1 on Projects 1 Mile or Less in Length.

(B) Travel-Way Is Defined As Total Width of a Travel Facility That Is Not Separated from Other Parallel Travel Facilities by a Median, Ditch, Etc.

SURFACE TREATMENTS

AGGREGATE	Gradation	Tex-200-F (Dry)	At Source or At Point of Delivery	Each 300 C.Y. Min. 1	Same as Job Control	1 Out of 20 Job Control Tests Min. 1		Record Testing Not Required Where D-9 Provides Job Control Testing
ASPHALT	Compliance With Item 300 "Asphalts, Oils and Emulsions"	Tex-500-C Etc.	Sampled, Tested, and Approved by D-9					

Rev., Oct., 1966

Fig 12. Materials sampling guide schedule (after Ref 72).

ASPHALTIC CONCRETE PAVEMENTS

GUIDE SCHEDULE
OF
MINIMUM SAMPLING AND TESTING PER CONTRACT

MATERIAL or PRODUCT		TEST FOR	TEST NUMBER	JOB CONTROL TESTS: LOCATION or TIME of SAMPLING	JOB CONTROL TESTS: FREQUENCY of SAMPLING	PROGRESS RECORD TESTS: LOCATION or TIME of SAMPLING	PROGRESS RECORD TESTS: FREQUENCY of SAMPLING	FINAL RECORD TESTS	REMARKS
MINERAL AGGREGATES (PRIOR TO MIXING)	COARSE AGGREGATE	Gradation	Tex-200-F (Dry)	During Delivery to Plant or From Stockpile	Each 6,000 Tons	Same as Job Control	Each 60,000 Tons Min. 2 (A)		Tests To Be Made for Each Stockpile
		Deleterious Material and Decantation	Tex-217-F	As Designated by District Engineer or as Specified	Each 6,000 Tons	Same as Job Control	Each 60,000 Tons Min. 2 (A)		
		Plasticity Index	Tex-105-E	As Designated by District Engineer or as Specified	Each 6,000 Tons When Necessary	Same as Job Control	Each 60,000 Tons Min. 2 When Necessary (A)		
	FINE AGGREGATE	Gradation	Tex-200-F (Dry)	During Delivery to Plant or From Stockpile	Each 6,000 Tons	Same as Job Control	Each 60,000 Tons Min. 2 (A)		Tests To Be Made for Each Stockpile
		Plasticity Index	Tex-106-E	During Delivery to Plant or From Stockpile	Each 6,000 Tons	Same as Job Control	Each 60,000 Tons Min. 2 (A)		
	MINERAL FILLER	Gradation	Tex-200-F (Dry)	During Delivery to Plant or From Stockpile	Each 6,000 Tons	Same as Job Control	Each 60,000 Tons Min. 2 (A)		
	COMBINED AGGREGATES	Gradation	Tex-200-F (Dry)	Hot Bins	4 For Each Normal Day's Production	Same as Job Control	Each 30,000 To[illegible]		Mineral Filler Not To Be Included
		Sand Equivalent	Tex-203-F	Hot Bins	1 For Each 10 Days' Normal Production				
ASPHALTS, OILS & EMULSIONS		Compliance With Item 300 "Asphalts, Oils and E[illegible]"	Tex-[illegible]						
			Tex-207-F	Plant or Road	1 For Each Normal Day's Production	Same as Job Control	1 For Each 10 Days' Normal Production Min. 2 (A)		
COMPLETE MIXTURE	HOT MIX ACP & HOT MIX-COLD LAID ACP	Stability	Tex-208-F	Plant or Road	1 For Each Normal Day's Production	Same as Job Control	1 For Each 10 Days' Normal Production Min. 2 (A)		
		Extraction	Tex-210-F	Plant or Road	1 For Each Normal Day's Production	Same as Job Control	1 For Each 10 Days' Normal Production Min. 2 (A)		
		In Place Density (When Required by Specifications)	Tex-207-F	Completed Course	1 For Each Normal Day's Production	Same as Job Control	1 For Each 10 Days' Normal Production Min. 2		
		Cohesiometer (When Required by Specifications)	Tex-214-F	Plant or Road	1 For Each Normal Day's Production	Same as Job Control	1 For Each 10 Days' Normal Production Min. 2 (A)		
		Moisture Content	Tex-212-F	Plant or Road	1 For Each Normal Day's Production (C)	Same as Job Control	1 For Each 10 Days' Normal Production Min. 2 (A)		
		Hydrocarbon Volatile Content	Tex-213-F	Plant or Road	1 For Each Normal Day's Production (C)	Same as Job Control	1 For Each 10 Days' Normal Production Min. 2 (A)		
	COLD MIX LRA PAVEMENT	Compliance With Item 330 "Cold-Mix Limestone Rock Asphalt"	Tex-217-F Etc.	Sampled, Tested, and Approved by D-9					
		Dimensions		Completed Pavement	As Necessary for Control			1 Depth & 1 Width Per Travel-Way Per Mile (B) Min. 3-Max. 10	

(C) Sampled, Tested, and Approved at Source Where D-9 Provides Inspection at Plant.

(A) Not Required Where D-9 Provides Inspection at Plant.

(B) Travel-Way Is Defined As Total Width of a Travel Facility That Is Not Separated from Other Parallel Travel Facilities by a Median, Ditch, Etc.

Rev., Oct., 1966

Fig 13. Asphalt surface sampling guide schedule (after Ref 72).

Factor (1) has received much attention and procedures for data acquisition are well developed (Refs 31, 84, and 85); procedures for factors (2) and (6) are standardized to a degree in Ref 73; Lytton discusses methods for quantifying factors (3), (4), and (5) in Ref 53. A forthcoming revision to Ref 73 is expected to clarify the procedures for acquiring swelling clay parameters and should be consulted in conjunction with the theory presented in Ref 53.

Future Action

Because the THD districts are highly autonomous, it is imperative that one or more of them be selected for PFDS pilot implementation on the basis of their interest. The plan of action should then be:

(1) Review the array of essential factors proposed herein and add those meeting some agreed essentiality criteria. On this point, it will be vitally important for someone to constantly stress the importance of eliminating data as discussed previously or data volume will grow without bounds.

(2) Examine existing district data collection plans to determine how many PFDS essential factors are already being sampled.

(3) Evaluate the existing data collection procedures to be satisfied that sampling is consistent with concepts previously discussed.

(4) Device sampling plans and procedures for the remaining essential factors.

With the new remote computer terminals in the district headquarters, the option of inputting data via punched cards (or some other medium) should be explored with D-19. However, this action should probably be deferred until MARK IV is fully operational and D-19 has had time to publish some basic operating procedures.

CHAPTER 8. FILE STRUCTURE AND DATA ANALYSIS

Overview of System and File Structure

This chapter was written for the pavement engineer, not the computer programmer or systems analyst. The latter two may even cringe at the liberties taken herein with computer systems terminology, but the object is to clearly depict to the practicing engineer some basic features of the proposed PFDS files. It is readily acknowledged that some of the resulting illustrations do not reflect the precise form of the computer handling of the data but it is contended that there is no harm done by looking at them in this way (see later discussion titled "File Combinations").

Another important point to emphasize is that this discussion is generalized and applies to no particular data handling system or language. The MARK IV file handling system now being introduced in the Texas Highway Department has its own way of defining, creating, and processing files, trailer files, temporary files, etc. The options in MARK IV far exceed anything envisioned herein, so the computer programmer will be able to easily define the desired file manipulations with the system.

The basic concept of the PFDS file structure is to store all design values in "prime" files and all as-built and subsequent detailed values in "trailer" files. The trailer files can be processed individually or together with their prime file (Ref 42). Each of the PFDS files as described in Chapter 5 will be illustrated and described in order to make the operating concept clear.

First, however, an overview of the file structure will be helpful to identify major groupings of data fields. Figure 14 shows both the conceptual prime and trailer file structure. Note that two differences are illustrated:

(1) The record control key for the trailer file is longer than for the primary. Since the records in the trailer file are detailed components of the prime file records, it is necessary to extend the data definition.

(2) The data fields are fewer in the trailer file. This simply illustrates that, in general, not all factors present in design need additional sampling in time and space. Therefore, only those factors to be further sampled are found in the trailer file.

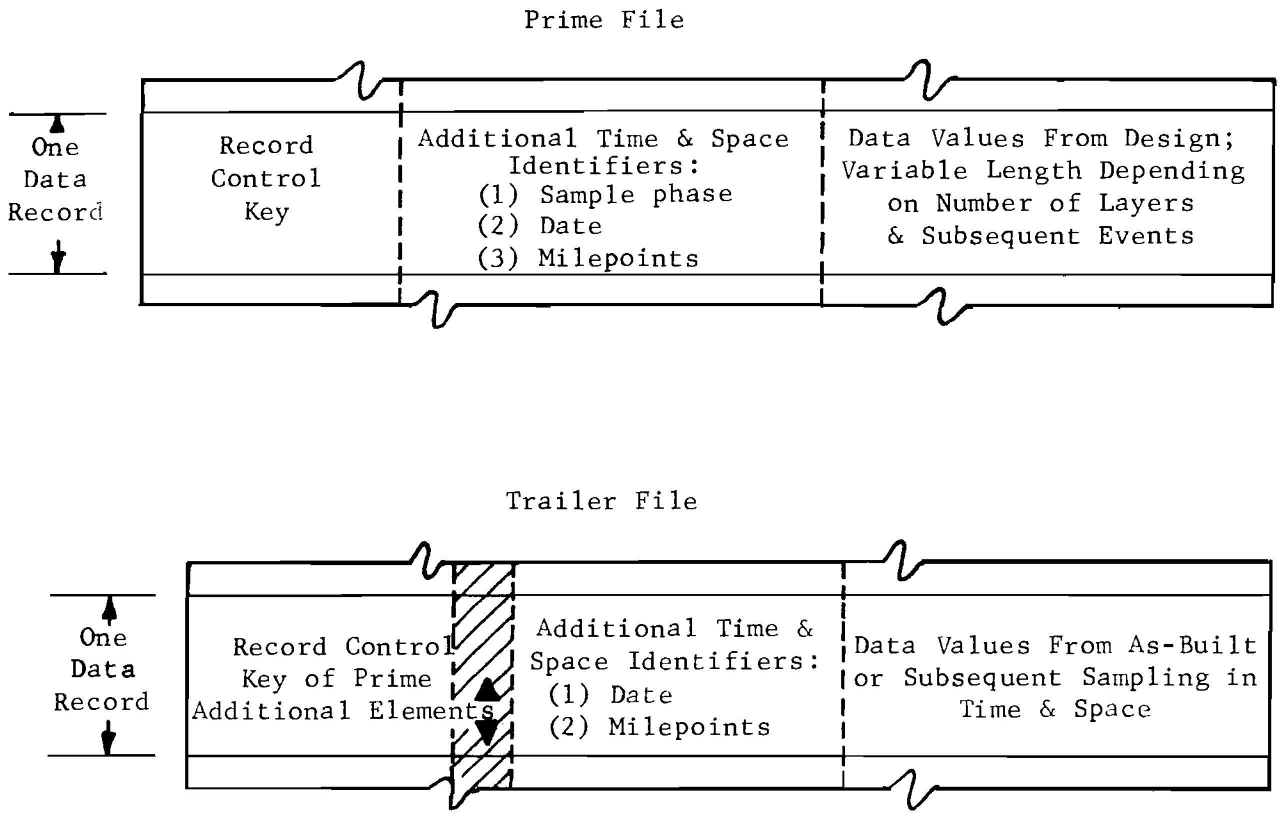

Fig 14. Overview of conceptual file structure.

There are some minor deviations from the structures shown in Fig 14 and they will become evident when the files are examined. Essentially, the deviations amount to certain omissions of data fields not needed. This is particularly evident in the environment and costs trailer files.

One objective in structuring these files has been to preclude as many "embedded" empty data fields as possible. This is accomplished primarily by utilizing variable length records that are extended or collapsed to fit the requirements of the particular record. For example, if a data record contains data on a two-layer pavement, no provision is made for a nonexistent third layer that might ordinarily exist. This should conserve storage space although storage for PFDS will probably not be a problem for a long time.

Data Coding

A determined effort has been made to keep data coding to an absolute minimum in order to keep the system input and output as readable as possible. However, a certain number of codes appears desirable and they have been devised to be as logical as possible. They apply to all files shown in Figs 15 to 22. Coding used in only one file is defined in the legend on the corresponding figure. The following definitions and codes are applicable:

(1) Sample phase: designates the time when data values are to be acquired as indicated also in Table 2. The following numbers designate

1. design values
2. as-built values
3., 4., 5., etc. subsequent measurements in time.

(2) Date: always a 4-digit number, the first two digits being year and the second two designating the month.

(3) Layer designation and code: these entries are generally the same as those used in FPS-11; layers are designated 1, 2, 3, etc. and materials A, B, C, etc. as part of the program input. Two additional codes that may be used in this field are: OL = overlay and SC = seal coat .

(4) Sample number: sequentially assigned numbers within a sample phase to identify number of the sample value. These numbers uniquely identify the sample with date and milepoint and may go to 99.

Decimal points have been omitted in most of the illustrations to conserve space. This is analogous to the assumed decimal points in the actual data files to conserve storage space.

Structural File

Figures 15 and 16 depict the prime and trailer structural files. Representative numbers have been entered to illustrate how the file records would be collated; dashes indicate that the entry in the preceding record is still valid in that field and to help accent record changes.

Note that in Fig 15 each job number is one record in the prime file, and all the pertinent design data appear in that one record. The result is a very long record; for a three-layer design with two subsequent overlays and design comments limited to 80 characters, the record length would be over 200 columns. This length could be reduced by shortening the names of materials to an abbreviation, etc. However, there may be many instances where the design comments should be longer than 80 columns. It is therefore suggested that all of the comments be designed into trailer records as described by Ref 42 and equated in the MARK IV system. This should pose no difficulty for the programmer.

In the trailer file depicted in Fig 16 there can be several records for each job number because of the need for specific date and milepoint sampling. For this reason, the record control key must have two additional fields to uniquely identify the record. As pointed out in Chapter 4, the record control key must be given exactly to the system or the record cannot be located in a random access environment. Since milepoint computed to three decimals may be difficult to recover at a later date, it is not a good key component. Therefore it is proposed as an item of data since its presence in the file is essential.

The multiple samples for any job number define the variability inherent in construction practices, the principal objective of this file structuring. Note that this trailer file should always contain the as-built data, sample phase code 2.

Description of one series of the illustrated data examples should help to clarify these and subsequent figures. In Fig 15, the first record shown is job number 1550 in control 2374 section 15. The design of this project was an asphaltic concrete surface five inches thick and a gravel base 12 inches

District	Control	Section	Job Number (.x)	Roadway	Lane	Sample Phase	Date (year, month)	Begin Milepoint (.xxx)	End Milepoint (.xxx)	Material Code	Layer Thickness (.x)	Stiffness Coefficient (.xx)	Material Code	Layer Thickness (.x)	Stiffness Coefficient (.xx)	Texas Triaxial Class (.x)	Event (Type of Work)	Date (year)	Layer Thickness (.x)	Stiffness Coef. (.xx)	Design Comments
02	2874	15	1550	1	2	1	6001	27333	32575	AC	50	80	GR	120	50	30	OL	55	20	75	
—	—	—	1570	1	2	1	6601	27333	32575	AC	20	80									
—	—	—	1590	1	2	1	7102	27333	32575	AC	30	80									
—	—	16	0510	1	0	1	6103	25232	28622	AC	20	75	LS	100	60	28	OL	42	20	75	
Record Control Key						Time & Space Identifiers				Surface Layer (as-built)			Repeat for Each Additional Layer				Repeat for Each Additional Event				

Notes: (1) Each row equals one record.

(2) In programming, a count field will be inserted before each repeated series of fields, i.e., before subsurface layers and events.

Fig 15. Structural prime file.

District	Control	Section	Job Number (.x)	Roadway	Lane	Sample Phase	Sample Number	Date (year, month)	Milepoint (.xxx)	Material Code	Layer Thickness (.x)	Stiffness Coefficient (.xx)	Material Code	Layer Thickness (.x)	Stiffness Coef. (.xx)	TTC*(.x)	
02	2374	15	1550	1	2	2	01	6101	27333	AC	45	75	GR	115	55	30	. . . . . .
–	–	–	–	–	–	–	02	–	27500	–	47	75	–	116	–	–	
–	–	–	–	–	–	–	03	–	27600	–	45	75	–	119	–	–	
02	2374	15	1570	1	2	2	01	6606	27333	AC	20	75					
–	–	–	–	–	–	–	02	–	27400	–	21	–					
–	–	–	–	–	–	–	03	–	27500	–	22	–					

← Record Control Key → (District through Sample Number)

← Time & Space Identifiers → (Date, Milepoint)

← Surface Layer (as-built) →

← First Subsurface Layer Repeat for Each Additional Layer →

*TTC - Texas Triaxial Class.

Note: Insert count field before first subsurface layer.

Fig 16. Structural trailer file.

thick. Only one overlay is illustrated at 5.5 years after initial construction. The next record is for job number 570, and contains the design values for the overlay predicted in job number 1550; note that it was designed exactly six years after the initial pavement construction.

The first three records illustrated in Fig 16 are individual as-built samples from the initial construction of job number 1550. The next three records show as-built samples taken from the overlay constructed five months after design and five years and five months after construction of the initial pavement. This latter value corresponds to the 5.5 years predicted in inital design.

The horizontal rows of dots between records in all figures represent records omitted. In Fig 16, an unspecified number of additional as-built samples from both the initial construction and overlay have been omitted. Job number 1560 has also been omitted but will be seen to be a special maintenance project in the cost files (Figs 21 and 22).

Environment File

Figure 17 shows the proposed environment prime file structure with sample entries to illustrate how the records would be sorted. Again, this file contains only design data, sample phase code 1, and each record is a different job number. The trailer file is shown in Fig 18; note that the milepoint field has been deleted. Since swelling clay data are generally representative of entire projects, single observed values for swelling probability and swell rate constant for the entire project (job number) are probably all that is required. Milepoints for job numbers are contained in the prime file. Note also that the sample number field is not needed when the specific milepoint is not used.

A value for potential vertical rise is shown for subsequent sampling phases but not for the as-built phase, and this warrants a brief explanation. This is intended to depict a possible way of collecting meaningful data on this parameter. Specifically, potential vertical rise is a long-term effect and no new evidence on its value is likely to be uncovered during construction. However, during the life of the pavement, the vertical rise should be measurable and these values can be used to verify estimates made during design. Therefore, the subsequent (sample phase 3 and 4) values of vertical rise shown

Record Control Key						Time & Space Identifiers				Data			
District	Control	Section	Job Number (.x)	Roadway	Lane	Sample Phase	Date (year, month)	Begin Milepoint (.xxx)	End Milepoint (.xxx)	Temperature Constant	Swell Probability (.xx)	Potential Vertical Rise (.x)	Swell Rate Constant (.xx)
...	...	...	...	...	...	...	...	...	...	...	...	...	...
02	2374	15	1550	1	2	1	6001	27333	32575	22	50	72	18
–	–	16	1300	1	0	1	6207	02375	05222	22	35	22	09
–	2377	05	0500	0	0	1	6102	15222	22170	22	70	55	20
03	0010	02	0070	0	0	1	6007	10175	15186	22	65	27	12
...	...	...	...	...	...	...	...	...	...	...	...	...	...

Fig 17. Environment prime file.

District	Control	Section	Job Number (.x)	Roadway	Lane	Sample Phase	Date (year, month)	Swell Probability (.xx)	Potential Vertical Rise (.x)	Swelling Rate Constant (.xx)
...	...	...	...	...	...	...	...	...	...	...
02	2374	15	1550	1	2	2	6101	60		15
—	—	—	—	1	2	3	6112	55	10	15
—	—	—	—	1	2	4	6212	55	15	15
—	—	16	1300	1	0	2	6202	60	49	09
...	...	...	...	...	...	...	...	...	...	...
← Record Control Key →							Time ID	← Data →		

Fig 18. Environmental trailer file.

in Fig 18 are cumulative values to be compared to value of 7.2 used in design (see Fig 17).

Since the temperature constant is assumed fixed within each district, there is no need to repeat values for it in the trailer file. However, if additional research shows localized temperature constants to be significant, there must be a field in the prime file for it and such has been provided.

Performance File

Figures 19 and 20 illustrate the prime and trailer performance files. These files conform very closely to the conceptual file plan illustrated earlier. The explanation of the design confidence level code is given in Fig 19. Since these data are point data for the most part, the trailer file must accomodate both time and space sampling as shown.

Costs File

This file deviates from the conceptual structure to a greater degree than the others. The prime file shown in Fig 21 has the typical record control key and the usual time and space identification fields. Each record is a separate job number containing design data (estimate of cost) as is true for other prime files. However, note that job number 1560 has data entries for routine maintenance only. This value is computed per square yard and will cumulatively compare with the design value of 0.13 shown as routine maintenance cost in the first record. Since all special maintenance projects, as well as overlays, seal coats, and construction, receive separate job numbers, the estimated costs for each will always appear as design values (sample phase 1) in this file. The trailer file in Fig 22 has the usual record control key minus sample number, since no milepoints are needed. To simplify these data items, a new field entitled type work has been introduced; codes are as shown. Numerical entries are as-built pavement costs per square yard. These values are directly comparable to the costs shown for the corresponding job numbers in the prime file.

Traffic File

The traffic file is not depicted herein since it is anticipated that all necessary traffic data can be obtained from the D-10 files. The only things

Record Control Key						Time & Space Identifiers				Data		
District	Control	Section	Job Number (.x)	Roadway	Lane	Sample Phase	Date (year, month)	Begin Milepoint (.xxx)	End Milepoint (.xxx)	Serviceability Index (.x)	Min. Serviceability Index (.x)	Design Confidence Level
02	2374	15	1550	1	2	1	6001	27333	32575	42	30	C
—	—	16	1301	1	0	1	6207	02375	05222	42	30	C
—	2377	05	0500	0	0	1	6102	15222	22170	40	25	B
03	0010	02	0070	0	0	1	6007	10175	15186	42	30	B

Legend

Design Confidence Level:

A = 50 percent D = 99 percent
B = 80 percent E = 99.9 percent
C = 95 percent F = 99.99 percent

Fig 19. Performance prime file.

District	Control	Section	Job Number (.x)	Roadway	Lane	Sample Phase	Sample Number	Date (year, month)	Milepoint (.xxx)	Surface Curvature Index (.xxx)	Serviceability Index (.x)
02	2374	15	1550	1	2	2	01	6101	27500	08	43
—	—	—	—	—	—	—	02	—	28500	10	41
—	—	—	—	—	—	—	03	—	29500	09	39
—	—	—	—	—	—	—	04	—	30500	11	39
—	—	—	—	1	2	3	01	6112	27500	09	40

← Record Control Key → (District through Sample Number) | Time & Space Identifiers (Date, Milepoint) | ← Data → (Surface Curvature Index, Serviceability Index)

Fig 20. Performance trailer file.

Record Control Key						Time & Space Identifiers				Data		
District	Control	Section	Job Number (.x)	Roadway	Lane	Sample Phase	Date (year, month)	Begin Milepoint (.xxx)	End Milepoint (.xxx)	Initial Construction Cost ($.xx/sy)	Overlay Construction Cost ($.xx/sy)	Routine Maintenance Cost ($.xx/sy)
02	2374	15	1550	1	2	1	6001	27333	32575	433	286	013
—	—	—	1560	1	2	1	6012	27000	33000	0	0	005
—	—	—	1570	1	2	1	6512	27000	33000	0	192	0
—	—	—	1590	1	2	1	7101	27500	33500	0	295	0

Fig 21. Costs prime file.

District	Control	Section	Job Number (.x)	Roadway	Lane	Sample Phase	Date (year, month)	Type Work	Project Pavement Cost ($.xx/sy)
02	2374	15	1550	1	2	2	6101	C	475
—	—	—	1560	1	2	2	6202	M	060
—	—	—	1570	1	2	2	6607	OL	225
—	—	—	1590	1	2	2	7107	OL	317

← Record Control Key → (District through Sample Phase); ← Data → (Type Work and Project Pavement Cost)

Legend

Type Work: C = construction
M = maintenance
OL = overlay
SC = seal coat

Fig 22. Costs trailer file.

needed are the name of the file and its structure; both are readily available from D-10. However, the data file is currently a sequential file (on tape). When the file is redefined in MARK IV, random access to the data will be possible. This step does not appear too far away and complete random access to the traffic data should be possible by the time PFDS is functioning in MARK IV.

Constraints File

The constraints file has not been illustrated since it is a simple listing of the remaining design values (FPS program inputs) for a project (job number). Contained herein are all factors that are designated as constraints in Table 2. The data factors shown as constraints in Table 2 will be sequentially arrayed in records with the standard key described in Chapter 4. This file is static and will be used only to reconstruct the design input listing (see Fig 25).

A Reference File

One reference file could be an extremely valuable asset for intelligent and efficient manipulation of the other PFDS data files already described. Specifically, a file that ties all job numbers to their specific control and section would be very helpful. In addition, some basic information about the job number could be included. Possibilities are

(1) date performed,
(2) type work,
(3) milepoint limits, and
(4) total cost (all work).

Inclusion of all of the above information might be a first step to automating the records in the control section office of D-8. Such action should be carefully considered by the personnel responsible. The total cost field would give PFDS users a bit of management information in highly accessible fashion. Insertion of the milepoint limits could make it possible to eliminate this field from the other PFDS files; this should be carefully evaluated by systems analysts to see if it would result in an acceptable file processing environment in MARK IV. For the present, it is suggested that the file be kept simple and limited to job number, date, and type of work. This file is illustrated in Fig 23. It makes possible the immediate retrieval of the essential

District	Control	Section	Job Number (.x)	Date (year, month)	Type Work	Job Number (.x)	Date (year, month)	Type Work	Job Number (.x)	Date (year, month)	Type Work	Job Number (.x)	Date (year, month)	
02	2374	15	0010	2906	C	0020	3007	M	0030	3112	M	0040	3201	...etc.
02	2374	16	0010	3107	C	0030	3212	M	0070	3511	OL	0080	3606	
03	2100	02	0010	3212	C	0020	3306	M						
21	0071	10	0010	2912	C	0020	3012	M	0040	3106	SC	0050		

Record Control Key ← → Job Numbers Applicable to Pavement Work - As Long As Needed

Note: In programming, insert count field before first series of job number fields.

Fig 23. A reference file.

information needed for interaction with the other PFDS data files. Only job numbers back to and including the last reconstruction of the entire control section need be entered for an adequate reference file.

File Combinations

Inclusion of the milepoints in the reference file, as discussed above, should be carefully evaluated in light of the increased file processing made necessary by such data deletion in other files. Perhaps such an action would conserve storage space at an unreasonable expense of retrieval and/or update time. The systems analyst must weigh this in an operational environment and make a judgment.

However, some reduction in media storage can be realized by judicious combinations of certain files having the same basic characteristics. Two such combinations appear reasonable:

(1) the environment, performance, and cost prime files (Figs 17, 19, and 21 respectively), and

(2) the structure and cost trailer files (Figs 16 and 22).

In each of the above cases, the data fields are comparatively short and could be stacked behind each other in each record to allow use of the same record control key field and time and space identification field. It is strongly suggested, however, that this computer programming action be accomplished without complicating the file use for the engineer. In other words, while the files may actually be combined as far as the programmer is concerned, the engineer should be able to interact with the system as though they were separate files.

Another programming aid might be mentioned here. As noted on Figs 15, 16, and 23, a count field is necessary in advance of repeated fields of data in records of variable length. This entry designates the number of times the data series is repeated in the file, i.e., the number of layers, job numbers, or events.

Prospects with MARK IV

When existing D-10 files are redefined in MARK IV, the files and fields will be given names that are needed to access the data. This will be true for PFDS as well. Ten standard forms are available to define and manipulate the data base in MARK IV and the instructions on use of them is a separate volume of its own (Ref 44). However, the action required by the average user should not be difficult to learn. D-10 and D-19 are currently studying this phase of the system. One especially powerful asset is the ability to change file structures with little effort. This is a very desirable feature in any system and especially attractive with a new data base.

Data analysis with MARK IV is somewhat limited although the operations possible are very easily invoked by terse entries on the standard form (see Fig 28). The following data manipulations are available:

(1) Sorting of values in sequence, ascending, or descending.

(2) Provision of summaries as follows:

  (a) total value of items,
  (b) cumulative value of items,
  (c) count number of items,
  (d) select maximum value,
  (e) select minimum value, and
  (f) compute average value.

Custom-Written Analysis Programs

There are some mathematical analyses necessary for PFDS that are not possible or practical with MARK IV. However, it is possible to access the MARK IV files with a custom-written analysis routine or module and perform the desired computations. The analysis module can be written in a high level language such as FORTRAN or PL/1.

Some rather elaborate analysis routines can easily be envisioned as desirable management tools. Event-triggered reports, for example, would be a great aid and might be typified by a serviceability loss prediction that is automatically triggered when the design life performance curve projects to a service life less than 85 percent of design life (or some other percentage). Such a computation could be automatically invoked each time a serviceability index, traffic, or surface curvature index value is input to PFDS. An illustration of this is given in Fig 24 where the as-built serviceability index was well below the design value of 4.2. The moment the as-built value of 3.9 is input to PFDS, the performance curve projection is computed by the analysis

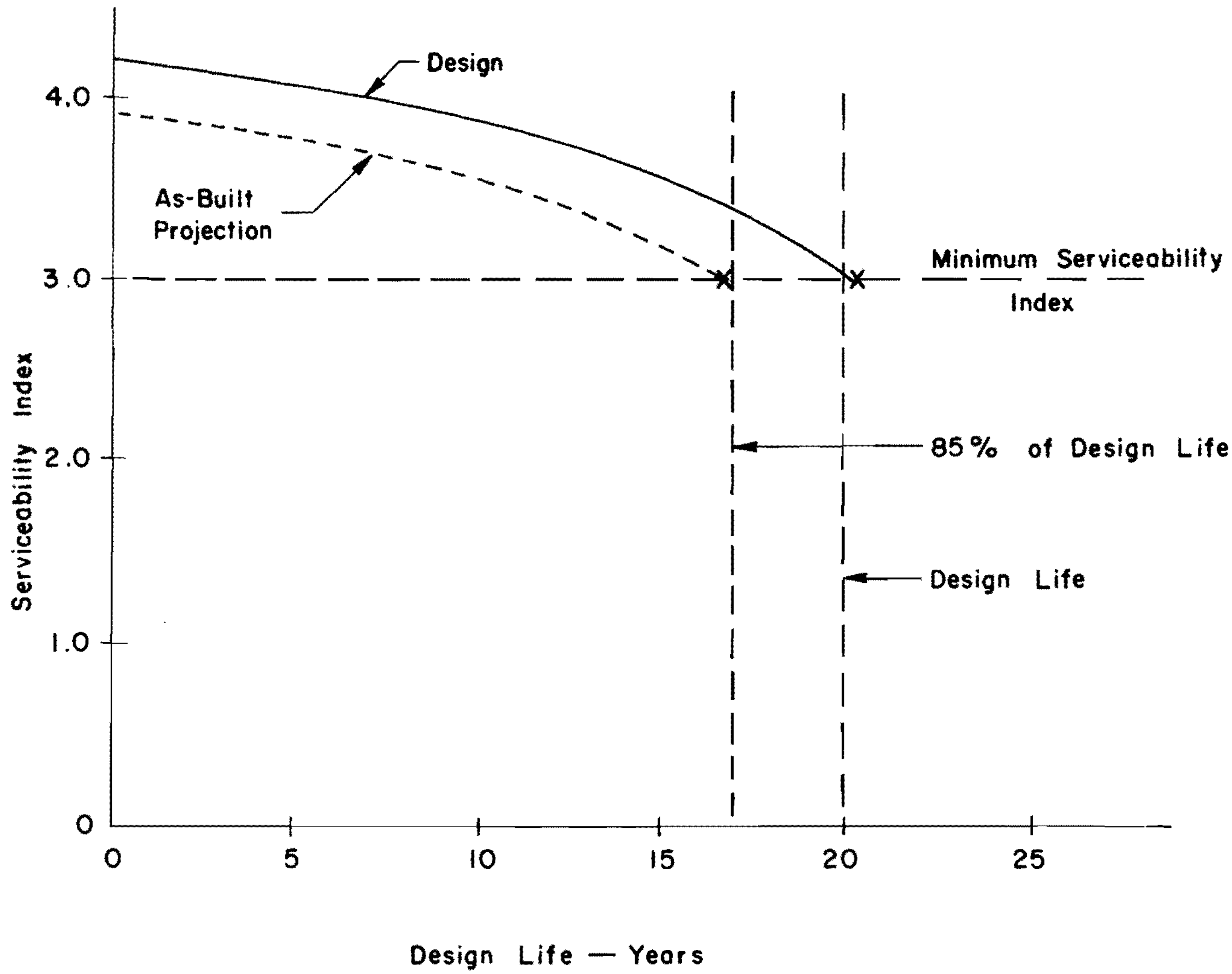

Fig 24. An event-triggered report of serviceability life of pavement.

module and intersects the minimum serviceability index level just before the 17th year of service. The pavement engineer may then expect a higher cost of maintenance or plan an earlier overlay to prevent accelerated damage due to dynamic loads.

A good deal of imperfection in the existing models may make such analyses as described above somewhat premature. Perhaps, a better feeling for the distribution of data values is needed first. It is therefore suggested that the initial analysis routines be limited to the following:

(1) A program to re-create the FPS-11 design inputs in the conventional order, as illustrated in Fig 25. This will involve extracting the design values from each of the PFDS prime files and combining them with the constraints file. This will permit a complete reevaluation of the design decision at a later date and allow direct comparison of design estimates versus actual performance.

(2) A routine containing the following performance model (Ref 68):

$$N = \frac{Q\alpha}{KS^2}$$

where

N = 18-kip single axles

Q = $\sqrt{5 - P} - \sqrt{5 - P_1}$

P_1 = initial serviceability index

P = present serviceability index

α = district temperature constant

S = surface curvature index

K = regression coefficient

(3) A routine with the swelling clay model (Ref 53):

$$P = P_1 - f(\alpha_1, \alpha_2, C_1, C_2, C_3, t)$$

where

P = present serviceability index

P_1 = initial serviceability index

TEXAS HIGHWAY DEPARTMENT
FPS - 11
FLEXIBLE PAVEMENT DESIGN

PROB	DIST.	COUNTY	CONT.	SECT.	HIGHWAY	DATE	IPE	PAGE
1B	14	TRAVIS	3136	01	LP 1 MOPAC	12/28/71	238	1

BASIC DESIGN CRITERIA

LENGTH OF THE ANALYSIS PERIOD (YEARS)	20.0
MINIMUM TIME TO FIRST OVERLAY (YEARS)	4.0
MINIMUM TIME BETWEEN OVERLAYS (YEARS)	6.0
MINIMUM SERVICEABILITY INDEX P2	3.0
DESIGN CONFIDENCE LEVEL	E
INTEREST RATE OR TIME VALUE OF MONEY (PERCENT)	7.0

PROGRAM CONTROLS AND CONSTRAINTS

NUMBER OF SUMMARY OUTPUT PAGES DESIRED (8 DESIGNS/PAGE)	2
MAX FUNDS AVAILABLE PER SQ.YD. FOR INITIAL DESIGN (DOLLARS)	8.00
MAXIMUM ALLOWED THICKNESS OF INITIAL CONSTRUCTION (INCHES)	36.0
ACCUMULATED MAX DEPTH OF ALL OVERLAYS (INCHES) (EXCLUDING LEVEL-UP)	6.0

TRAFFIC DATA

ADT AT BEGINNING OF ANALYSIS PERIOD (VEHICLES/DAY)	39330.
ADT AT END OF TWENTY YEARS (VEHICLES/DAY)	64750.
ONE-DIRECTION 20.-YEAR ACCUMULATED NO. OF EQUIVALENT 18-KSA	5894000.
AVERAGE APPROACH SPEED TO THE OVERLAY ZONE(MPH)	50.0
AVERAGE SPEED THROUGH OVERLAY ZONE (OVERLAY DIRECTION) (MPH)	20.0
AVERAGE SPEED THROUGH OVERLAY ZONE (NON-OVERLAY DIRECTION) (MPH)	50.0
PROPORTION OF ADT ARRIVING EACH HOUR OF CONSTRUCTION (PERCENT)	5.5
PERCENT TRUCKS IN ADT	8.0

ENVIRONMENT AND SUBGRADE

DISTRICT TEMPERATURE CONSTANT	31.0
SWELLING PROBABILITY	0.85
POTENTIAL VERTICAL RISE (INCHES)	5.00
SWELLING RATE CONSTANT	0.08
SUBGRADE STIFFNESS COEFFICIENT	0.26

CONSTRUCTION AND MAINTENANCE DATA

SERVICEABILITY INDEX OF THE INITIAL STRUCTURE	4.0
SERVICEABILITY INDEX P1 AFTER AN OVERLAY	3.9
MINIMUM OVERLAY THICKNESS (INCHES)	0.8
OVERLAY CONSTRUCTION TIME (HOURS/DAY)	7.0
ASPHALTIC CONCRETE COMPACTED DENSITY (TONS/C.Y.)	1.26
ASPHALTIC CONCRETE PRODUCTION RATE (TONS/HOUR)	75.0
WIDTH OF EACH LANE (FEET)	12.0
FIRST YEAR COST OF ROUTINE MAINTENANCE (DOLLARS/LANE-MILE)	100.00
INCREMENTAL INCREASE IN MAINT. COST PER YEAR (DOLLARS/LANE-MILE)	10.00

DETOUR DESIGN FOR OVERLAYS

TRAFFIC MODEL USED DURING OVERLAYING	3
TOTAL NUMBER OF LANES OF THE FACILITY	6
NUMBER OF OPEN LANES IN RESTRICTED ZONE (OVERLAY DIRECTION)	1
NUMBER OF OPEN LANES IN RESTRICTED ZONE (NON-OVERLAY DIRECTION)	3
DISTANCE TRAFFIC IS SLOWED (OVERLAY DIRECTION) (MILES)	1.00
DISTANCE TRAFFIC IS SLOWED (NON-OVERLAY DIRECTION) (MILES)	0.0
DETOUR DISTANCE AROUND THE OVERLAY ZONE (MILES)	0.0

PAVING MATERIALS INFORMATION

LAYER	MATERIALS CODE	NAME	COST PER CY	STR. COEFF.	MIN. DEPTH	MAX. DEPTH	SALVAGE, PCT.
1	A	LT. WT. ACP	21.42	0.96	1.00	1.00	10.00
2	B	ACP	15.48	0.96	1.50	1.50	10.00
3	C	BLACK BASE	13.93	0.96	2.50	10.00	30.00
4	D	CRUSHED STONE	4.40	0.60	10.00	18.00	80.00
5	E	LIME TREATED SUBG	2.40	0.40	6.00	6.00	100.00

Fig 25. FPS-11 input data listing.

α_1 = .335

α_2 = .17

C_1 = swell probability

C_2 = potential vertical rise

C_3 = swell rate constant

t = time in years

(4) Routines accessing the stiffness coefficient and profile analysis computer programs explained in Ref 73. Care must be taken to insure that the data names in PFDS and these analysis programs agree. If PFDS is loaded on the MARK IV system, this will mean that the two analysis programs must be revised slightly to reconcile terminology.

(5) A statistical program to compute mean, variance, standard deviation, and coefficient of variation.

CHAPTER 9. PFDS INFORMATION POTENTIAL

PFDS Equals Information

The fundamental purpose of PFDS is to provide the engineer manager with "information," not just "data." Charles Kriebel of Carnegie-Mellon University emphasizes the importance of distinguishing the difference (Ref 51). While data are simply various forms of facts, information is the intelligence of retrieved data when put to use in context. This important distinction is that the information system (PFDS) should require focusing on the management functions in addition to the pure data processing activities. It is the purpose of this chapter to illustrate how PFDS addresses the information needs of the highway engineer users. In some respects, it could be considered the most important part of this report.

It is appropriate to recognize three distinct groups of potential PFDS users:

(1) the District Engineer and his staff,

(2) the administrative headquarters and divisions, and

(3) researchers.

Each of these groups will have a different type of information need. This was also discussed briefly in Chapter 7, Data Sampling, wherein the impact of data use upon sampling was considered. Throughout this report, an attempt has been made to emphasize the end use of data and the importance of building a data system responsive to the users.

Illustration of the potential use of PFDS by each of the above groups is given in the following sections. These illustrations are typical inquiries that might come from the engineer or manager and a typical response output from PFDS. It must be emphasized that the inquiry examples presented are not coded in any particular system except Figs 28 and 29; these two figures illustrate the MARK IV system. Emphasis has been placed on clarity rather than programming and coding accuracy.

Information for District Management

This user group is considered first for a very good reason. In most respects, the highway engineering job is being done by these field personnel and PFDS must therefore answer their needs first. As is pointed out in Chapter 10, the districts should be consulted early in the pilot implementation phase to insure that their needs will be satisfied.

The District Engineer is constantly faced with the judicious allocation of his men, money, and material resources to maintain the best possible highway system for the traveling public. PFDS can help him do this.

Serviceability index (SI) and skid resistance coefficient are two of the most important parameters to indicate how well a highway pavement serves the public. Therefore, when either or both of these factors begin exhibiting minimum values, it is time to perform some kind of maintenance or reconstruction. If this condition is further complicated by a relatively high use (high traffic) of the highway, the need for corrective action may become urgent.

Assuming data for these three parameters have been taken on the district highway network, the retrieval of the roughest, (low SI), or most slippery (low skid resistance coefficient) or high traffic (AADT) highway sections would be a relatively time consuming task if the records are in manual form. Compound this situation by requesting the retrieval of all pavement sections satisfying a specified constraint for each of the three parameters and the task becomes significantly large.

PFDS meets this need head-on. Figure 26 illustrates the instructions the District Engineer, for example, District 19, might give and the answers he would get from PFDS. He has specified that he wants a listing of all his pavements with an SI of 2.5 or below, a skid resistance coefficient of .35 or lower, and a traffic volume (AADT) greater than 500 vehicles per day. The computer output shows 14 sections that meet these conditions. This is a simple retrieval of the pavement sections identified by the record control key discussed in Chapter 4. Variation of the output format is achieved simply by adding the desired specifications to the request. For example, the District Engineer may have wanted the milepoint limits instead of or in addition to job number; a simple instruction to that effect would yield the desired information. The only constraint is that the requested parameter must be in at least one of the PFDS, skid resistance, or D-10 files.

*LIST: SI < 2.5 SKID-RESISTANCE < 0.35, AADT > 500, DISTRICT = 19.

DISTRICT	CONTROL	SECT	JOB NO	ROADWAY	LANE	SI	SKID RESIST	AADT
19	62	4	6	0	0	2.4	0.29	3013
19	62	4	8	0	0	2.1	0.32	3013
19	62	4	9	0	0	2.1	0.33	3013
19	62	5	5	0	0	2.3	0.30	3013
19	62	5	7	0	0	2.5	0.29	3013
19	62	6	3	0	0	2.5	0.28	3013
19	62	6	4	0	0	2.4	0.28	3013
19	62	6	5	0	0	2.1	0.32	3013
19	62	7	7	0	0	2.2	0.33	3013
19	83	8	2	0	0	2.0	0.31	774
19	83	8	3	0	0	2.3	0.31	774
19	83	9	5	0	0	2.2	0.33	774
19	83	9	6	0	0	2.3	0.32	774
19	83	9	9	0	0	2.4	0.30	774

Fig 26. Typical selective retrieval of pavement sections meeting specific conditions.

Information for Administration

Within the administrative user group are the Highway Commission, State Highway Engineer, and the headquarters divisions. Their needs for various kinds of information are often related to vital policy or programming actions and are therefore important in support of district efforts.

One relatively common activity is the review of pavement and highway designs accomplished by the districts. By combining their experience with all districts, the headquarters design review staff can help to preclude potential problems; they serve as a background upon which individual district problems can be projected to secure new, more reliable perspectives.

An example of the use of PFDS by the headquarters design review staff is illustrated in Fig 27. A district has submitted a set of plans specifying an asphalt-treated base, and the review staff wants to examine performance and location data on all pavements constructed with asphalt-treated bases in the past ten years. The constraints placed on the retrieval operation are those dictated by the particular design being reviewed. For the sake of simplicity, some important factors in pavement performance may not be explicitly shown and are assumed to be constant or not an influence in this case. Note that the PFDS output includes a computed value of serviceability loss per year. This type of data manipulation can be specified as desired. Once such analysis routines are written and used, they are catalogued and are available for use later simply by calling them by name.

The numbers reflected in this figure do not necessarily allow any conclusions about asphalt-treated base design. The real point of the illustration is that a tremendous amount of data has been screened to yield the desired information. If done manually, such an effort would entail months of effort; with PFDS, answers are available in minutes. Furthermore, no data are overlooked or forgotten as is frequently true with manual systems. The engineer is truly provided with the best possible feedback information to help him in his decision process.

Figures 28 and 29 illustrate the same retrieval operation in the MARK IV system. The initial complexity of the tabular format is quickly moderated after some brief study of the form. Training and experience with the system is needed to fully appreciate the simplicity and all of the advantages depicted here. For example, note that the four entries of the numeral one in

```
*LIST SECTIONS ALL DISTRICTS: LAYER-1 = (ACP), THICKNESS = 3.0,
LAYER-2 = (ASPHALT TREATED BASE), SWELL-RATE-CONSTANT < 0.04,
SWELLING-CLAY-PROBABILITY < 0.25.
```

DISTRICT	CONTROL	SECT	JOB NO	ROADWAY	LANE	DATE CONSTRUCTED	LAYER 2 THICKNESS	SI LOSS / YEAR
02	314	3	3	0	0	6810	8	0.21
05	297	5	7	0	0	6206	8	0.22
06	1140	3	6	0	0	6608	10	0.17
09	258	8	10	0	0	6712	10	0.15
12	338	3	7	0	0	6808	7	0.25
14	573	2	5	0	0	6910	12	0.10
17	212	2	7	0	0	6602	8	0.19
19	52[illegible]	4	9	0	0	6701	7	0.22
22	57	[illegible]	4	0	0	7006	14	0.05

Fig 27. Sample retrieval of design data.

MARK IV FILE MANAGEMENT SYSTEM®

Informatics Inc.®

INFORMATION REQUEST

PAGE 1 OF 1

DECK I.D (73–80):

* REQUEST NAME (1–8)	FORM CODE (9 10)	REPORT DATE (11–16)
PFDS	IR	TØDAY

REQUESTOR NAME (17)	TELEPHONE/EXT.	DIVISION/DEPT. (44)
ØG STRØM	411-1414	CFHR UT

MAXIMUM ITEMS SELECTED (45–48)	SELECTION CONTROL (49)	SUMMARY REPORT ONLY? (50)	VERTICAL SPACING (51)	FORMS CONTROL (52)	WIDTH OF PAGE (53)	HEIGHT OF PAGE (54)	LINE NUMBERS? (55)	SPECIAL REQUEST PROCESSING (56)
					B	B		

REPORT FORMAT: Summary report only? / Vertical spacing / Forms control / Width of page / Height of page / Line numbers?

RECORD SELECTION

FORM CODE 9,10	SEQ. NO. 11–13	LOGIC LEVEL 14	CONNECTOR 15	FIELD NAME A 17–24	OPERATION 25,26	BLANK, C OR D 27	FIELD NAME B OR CONSTANT 28–48
PR				LAYER1	EQ	C	ACP
PR			A	THICK1	EQ	D	5
PR			A	LAYER2	EQ	C	ATB
PR			A	THICK2	GT	D	6
PR			A	SWELL	LT	D	.25
PR			A	SWELLRAT	LT	D	.04
PR							
PR							
PR							
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PR							
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PR							

REPORT SPECIFICATION

FORM CODE 9,10	SEQ. NO. 11–13	NO. OF SPACES BEFORE COLUMN 14,15	FIELD NAME 17–24	SORT: SEQUENCE 27	SORT: DESC ? 28	BREAK: CONTROL 29	BREAK: SUBTITLE 30	SUMMARIES: TOTAL 31	SUMMARIES: CUM 32	SUMMARIES: COUNT 33	SUMMARIES: MAX 34	SUMMARIES: MIN 35	SUMMARIES: AVG 36
R1			DISTRICT	1									
R1			CØNTRØL										
R1			SECTIØN										
R1			JØBNUM							G			
R1			RØADWAY										
R1			DATE										
R1			LAYER2								1	1	
R1			SI								1		1
R1													
R1													
R1													
R1													
R1													
R1													
R1													
R1													

9 10	11 13	14 TITLE 72
T1	001	SAMPLE RETRIEVAL ØF DESIGN DATA

*KEYPUNCHING NOTE: THIS NAME MUST APPEAR IN COLS 1-8 OF ALL CARDS PUNCHED FROM THIS FORM.

Fig 28. MARK IV data retrieval request.

05/01/72 SAMPLE RETRIEVAL OF DESIGN DATA PAGE 2

DISTRICT	CONTROL	SECTION	JOB NO	ROADWAY	LANE	DATE CONSTR	LAYER THICK	SI LOSS/YR
2	314	3	3	0	0	68/10	8	.21
5	297	5	7	0	0	62/06	8	.22
6	1140	3	6	0	0	67/12	10	.17
9	258	8	10	0	0	68/08	10	.15
12	338	3	7	0	0	69/10	7	.25
14	573	2	5	0	0	66/02	12	.10
17	212	2	7	0	0	67/04	8	.19
19	520	4	9	0	0	70/06	7	.22
22	37	8	4	0	0	70/05	14	.05

GRAND COUNT 9

MAX.	14	.25
MIN.	7	
AVG.		.173

Fig 29. Example of MARK IV data output.

the three right columns produces the maximum, minimum, and mean values of the parameters designated (see Fig 29). It is difficult to conceive a more trivial programming task.

Information for the Research Engineer

The specific interests of the research engineer are served by PFDS as well. Just as the other groups of users can be assured of comprehensive data screening, the researcher can be confident that he has access to all the data collected. He need not fret that someone's "black book" was overlooked in his specific study area.

An example from the research realm might be a data retrieval and analysis operation to confirm (or deny) the theory that pavements exhibiting equivalent surface curvature indices (SCI) are equal in their traffic carrying capacity, regardless of their individual structural configuration. Figure 30 shows the PFDS output of District 15 data on performance of pavements with treated and untreated base courses. The analysis period is the first performance period only, i.e., to the first overlay. Data entries under the SCI levels are cumulative number of 18-kip single axle equivalents at time of overlay. It is assumed here that the overlays are performed when structural failure due to traffic has occurred; the constraints on swelling clay are intended to eliminate the factor from consideration in this problem.

The amount of data shown here are not sufficient to substantiate any firm conclusions, but there is an indication that the SCI theory may be invalid. For example, the traffic at failure for pavements with untreated bases, SCI range of 16 to 20 mils, varies from a low of 980,000 to a high of 2,030,000 18-KSA. Pavements with treated (cement) bases exhibit the expected lower SCI values but tend to require an overlay after fewer cumulative traffic applications. Again, the point is that PFDS not only contains the data needed to check and verify models but may provide the mechanisms to screen and manipulate data in any form desired by the researchers. The result should be greatly improved research efficiency and more research for each dollar invested.

REQUEST NO.571: LIST PAVEMENT SECTIONS, DISTRICT EQ 15, TRAFFIC EQ NUMBER 18 KSA *10**6 AT FIRST OVERLAY, RANGE OF SCI LEVELS EQ 5 MILS, SWELLING CLAY PROBABILITY LESS THAN 0.25 AND SWELL RATE CONSTANT LESS THAN 0.04, UNTREATED BASE (SPEC. NO. 232 503) THICKNESS GREATER THAN 7 INCHES AND LESS THAN 13 INCHES

REQUEST NO.572: LIST PAVEMENT SECTIONS, DISTRICT, TRAFFIC, SCI, SWELLING CLAY SAME AS REQUEST NO.571, TREATED BASE (SPEC. NO.274 511) THICKNESS SAME AS 571.

REQUEST NO. 571 (UNTREATED BASE):

DISTRICT	CONTROL	SECT	JOB NO	ROADWAY	LANE	BASE THICKNESS	SCI LEVELS 0-5	6-10	11-15	16-20	21-25
15	17	6	2	0	0	10				1.55	
15	143	6	3	0	0	8					1.82
15	328	4	8	0	0	8					1.95
15	470	3	5	0	0	10				0.98	
15	1740	1	4	0	0	12				2.03	

REQUEST NO. 572 (TREATED BASE):

DISTRICT	CONTROL	SECT	JOB NO	ROADWAY	LANE	BASE THICKNESS	SCI LEVELS 0-5	6-10	11-15	16-20	21-25
15	72	7	14	0	0	8		1.21			
15	72	5	13	0	0	8			1.13		
15	72	6	15	0	0	10		1.25			
15	142	14	17	0	0	10		1.49			

Fig 30. Sample retrieval of research data.

CHAPTER 10. PFDS IMPLEMENTATION STRATEGY

The three major phases or stages of PFDS implementation are defined as

(1) administrative decisions and actions,

(2) pilot implementation, and

(3) revision and extended implementation.

Each of these stages is composed of several distinct steps or sub-stages, and these are discussed in detail in the appropriate following sections.

Administrative Decisions and Actions

This grouping of specific steps should be considered priority actions generally in the order discussed.

(1) Take immediate action to interface the skid resistance, maintenance, and proposed pavement feedback data systems. At the present time, D-8R has an operating skid resistance data system for Districts 14 and 19; D-18 is formulating a maintenance data system in Districts 19 and 21. Interaction of the responsible sections is imperative to insure that development efforts finally yield compatible but non-duplicative data systems.

(2) In coordination with D-8, D-10, D-18, and D-19, administratively designate the record control key to be used in all automated highway system data files. In addition to the three systems mentioned above, the D-10 data files RL-1, Traffic Log and RI-2 must be standardized with the same record control key.

(3) Proceed with implementation of the MARK IV data handling system as quickly as possible. This action should include:

   (a) Training of D-8, D-10, D-18, and selected district personnel.

   (b) Definition in MARK IV of PFDS files as now conceived.

   (c) Redefinition in MARK IV of D-8R skid resistance files.

   (d) Redefinition in MARK IV of RL-1, Traffic Log, and RI-2.

   (e) Pilot runs of selected data file manipulations to check file and field compatibility.

(4) Procure the additional MARK IV features

   (a) Indexed Coordinated Files, to permit random access to the data base, and

(b) Extended File Processing, to allow increased multiple file processing.

(5) Accomplish initial coordination between D-8 and D-10 with the objectives of

(a) eliminating isolated problems with existing milepoint designations,

(b) beginning the inclusion of milepoints in RL-1, and

(c) revising design procedures to simplify later posting of pavement projects to RL-1 records.

(6) Select one or more districts to effect a pilot implementation of PFDS. This action should be guided by the trial implementation experience with FPS, the skid resistance data files and the maintenance data system now being formulated. Specifically, the districts to test PFDS should be selected from the following summary of the districts now working with the indicated design or data system:

FPS-11	Skid Resistance	Maintenance
1	9	19
2	14	21
5	19	
8		
11		
14		
15		
17		
19		
21		

The selection of district(s) should also consider availability of special equipment such as a Mays Road Meter. While no single district may be initially capable or desirous of pilot implementation of all PFDS files, enough districts should be selected to permit total coverage of the PFDS files (each file being pilot implemented by at least one district).

Pilot Implementation

This phase should consist of the following specific steps:

(1) Conduct initial PFDS orientation session for selected districts. This should include an overview of PFDS concepts and its intended

interaction with the applicable D-10 data files, skid resistance data system, and maintenance data system.

(2) Immediately incorporate the essential factors specified by the selected districts and define/redefine the PFDS data files in MARK IV accordingly. Selected districts(s) should review the Traffic Log, RL-1, and RI-2 with a view to evaluating acceptability of current data and/or pinpointing additional changes.

(3) Districts D-8 and D-10 should collaborate in development of some basic draft sampling plans to acquire the PFDS data on their respective interstate system. One or both of the research institutions should probably render assistance. This step should also include an inventory of existing district data acquisition procedures to

   (a) evaluate suitability of existing data,

   (b) effect necessary changes to existing data acquisition procedures,

   (c) isolate new data collection requirements, and

   (d) identify the logical district activity to carry out each PFDS data acquisition and reporting function.

(4) Begin data collection and insertion in MARK IV files for the interstate highway system. Priority should be given to those sections designed with FPS-11.

(5) Perform some basic data file manipulations to test interactive characteristics of all PFDS and related files (RL-1, RI-2, etc.)

(6) Convene a workshop to include pilot districts and D-8, D-10, D-18, and D-19, to evaluate the results of pilot implementation.

<u>Revision and Extended Implementation</u>

The preceding pilot implementation of PFDS should yield some very valuable experience, thus making possible a first major revision to PFDS and associated procedures, and permitting a markedly increased implementation participation. Steps in this next phase are:

(1) Development and publication of PFDS instruction manuals. This must be a joint activity of the pilot districts, D-8, D-10, D-18, and D-19. Again, the Texas Transportation Institute and/or Center for Highway Research could provide assistance in writing these manuals.

(2) Select additional districts to implement the full-scale PFDS. These districts should probably be those remaining on the FPS list shown previously. Conduct an orientation and training session for the new districts using manuals derived from the first step above.

(3) After a three-month trial period by the new districts, convene a feedback workshop to review findings. From this collection of experience, revise PFDS files and procedures as appropriate. Some

"customizing" of PFDS files by districts may be warranted to satisfy unique situations.

(4) Begin collecting data on the highway system in the following order, commensurate with resources:

(a) Selected FPS-designed pavements based on certain criteria

(b) Interstate system

(c) Remainder of system in order of traffic volumes.

(5) Conduct feedback workshop and rewrite instruction and operating manuals accordingly.

Implementation Summary

Several important features of this proposed implementation plan are worthy of special comment:

(1) No additional district or division personnel are envisioned as a requirement to implement PFDS. The existing district staffs will be trained to properly input data to and retrieve data from PFDS and the related files. The MARK IV training sessions now being conducted by D-19 should adequately meet these needs. Personnel now responsible for data collection should be able to satisfy PFDS needs by intelligent evaluation of current procedures and reallocation of resources to only valid requirements. In other words, close scrutiny of existing data sampling and usage will undoubtedly reveal that some of this effort can be diverted to satisfy PFDS needs with no adverse effects.

In the headquarters divisions, the effective implementation of PFDS will depend upon a reordering of existing priorities. It is suggested that currently available personnel resources are adequate to support the PFDS implementation plan if a realistic appraisal of potential and relative benefits is made.

(2) An open-ended iteration procedure for PFDS implementation is envisioned. Each loop expands upon the findings of the preceding one with a progressive increase of complexities. The pilot implementation phase can thus be considered as setting up a pattern for the succeeding phases. Figure 31 depicts a composite iteration of PFDS implementation.

(3) An additional and immediate expenditure of $10,000 is needed for the two additional MARK IV features. This sum may be reduced if some other agency of state government procures the features before the THD. Other costs will be incurred for measuring equipment on a progressive, phased basis, but no estimate of such costs can be defined at this time.

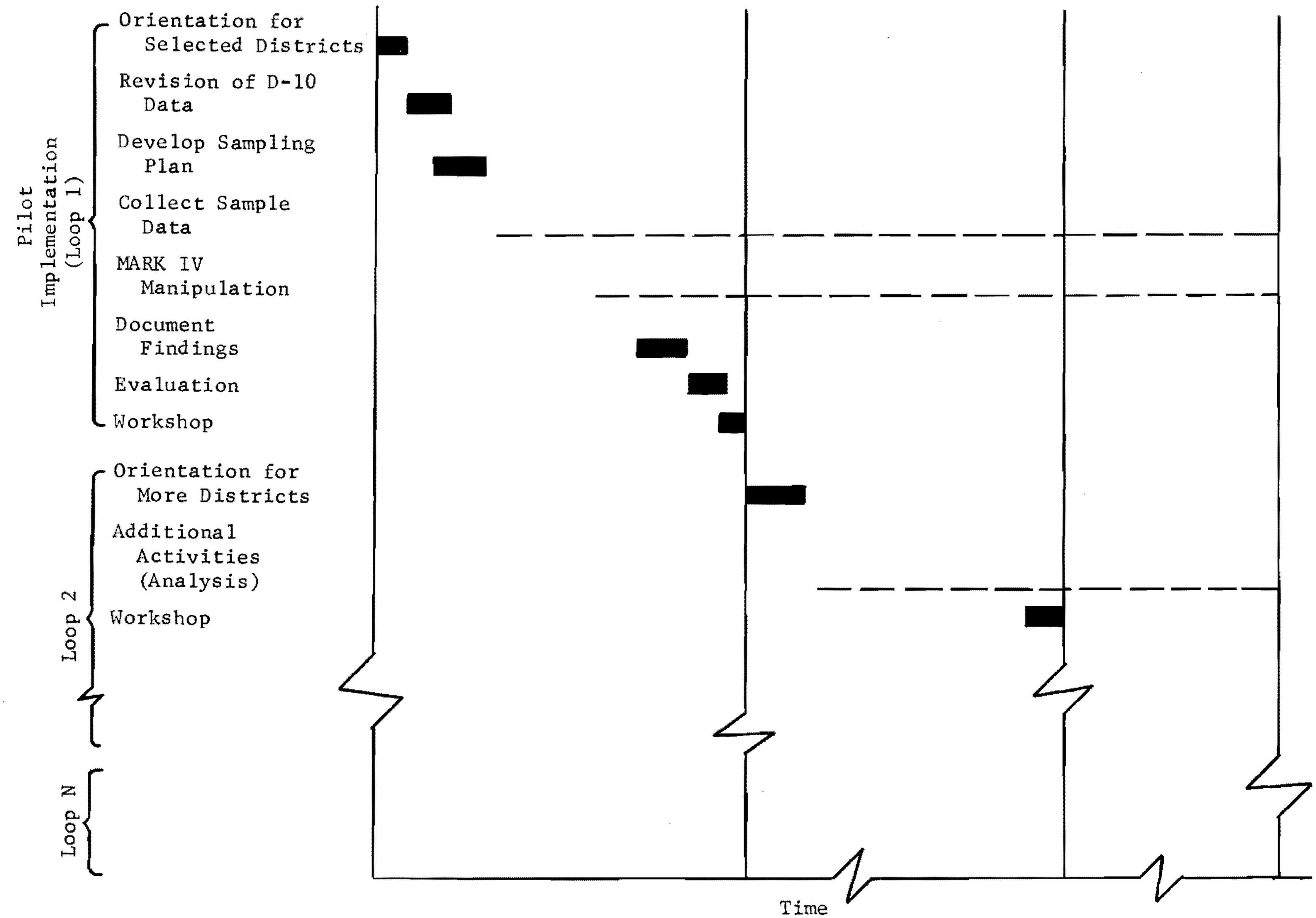

Fig 31. Composite iteration of PFDS implementation.

CHAPTER 11. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

An operational PFDS for flexible pavement systems is dependent upon the enthusiastic support and action of some user districts. The selection of one or more districts to pilot test the system will serve as excellent implementation and allow further refinement based on a wealth of experience and a variety of viewpoints. However, care must be taken to prevent potential data pollution discussed many times throughout this report.

The MARK IV file handling system provides THD with a powerful tool that should generate benefits for all divisions and districts. This common file handling environment may encourage a wider dissemination of vital highway information that may generate interest in more record automation thus increasing the information potential in the Department. The pay-off should be a more informed Department and a continually improving highway system.

Recommendations

(1) Begin immediately with PFDS implementation generally as outlined in Chapter 10.

(2) Perform appropriate research needed to define essential factors of maintenance; insert appropriately in PFDS as a special research file until verified by performance feedback.

(3) Begin identification of essential factors for rigid pavement design and management.

(4) Consider automation of the control section records in D-8.

(5) Evaluate need for a data files committee in THD to meet regularly to exchange information and eliminate data duplication.

(6) Using NWS temperature records, perform some within-district computations for temperature constant to ascertain whether localized values of this parameter would contribute to improvement in reliability of the FPS design procedure.

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APPENDIX A

ABBREVIATIONS

ABBREVIATIONS

AADT	-	Annual average daily traffic.
AASHO	-	American Association of State Highway Officials.
ACP	-	Asphaltic concrete pavement.
COGENT III	-	A COBOL - compatible generalized file management system developed by Computer Sciences Corporation.
DM-1	-	Data Manager -1, a generalized file management system designed by Auerbach Corporation.
FPS	-	Flexible pavement system.
GDMS	-	Generalized data management system.
GIS	-	Generalized information system, a collection of programs to support formatted file functions, designed/written by International Business Machines (IBM).
HNDI	-	Highway Network Data and Information System, the Wisconsin Department of Transportation technical data system.
ISAM	-	Indexed sequential access method, a programming method that allows rapid access to file records in random fashion.
KSA	-	Kips single axles, used with numeral 18 to designate the common traffic base of 18 kip single axles.
MARK IV	-	An advanced general-purpose data management system developed by Informatics, Incorporated.
MIS	-	Management information system.
NIPS	-	National military command information processing system, a general purpose file handling system adapted to military intelligence functions from IBM's formatted file system (FFS).
NTIS	-	National Technical Information Service, U. S. Department of Commerce, Springfield, Virginia 22151.
NWS	-	National Weather Service.
PFDS	-	Pavement feedback data system.
PL/1	-	Programming language 1, an IBM "super" version of FORTRAN and COBOL computer programming languages.
PSI	-	Present serviceability index, now commonly referred to only as SI, serviceability index.
RI-2	-	Road inventory file maintained by the Planning Survey Division of Texas Highway Department.
RL-1	-	Road life file maintained by the Planning Survey Division of Texas Highway Department.

SCI - Surface curvature index.

SI - Serviceability index, synonomous with PSI.

THD - Texas Highway Department.

Headquarters Divisions:

D-3 - Finance

D-4 - Equipment and Procurement

D-5 - Bridge

D-6 - Construction

D-8 - Highway Design

D-9 - Materials and Tests

D-10 - Planning Survey

D-18 - Maintenance Operations

D-19 - Automation

WISDOT - Wisconsin Department of Transportation.

APPENDIX B

PFDS SPECIFICATIONS AND MACRO COMPARISON OF GDMS

PFDS SPECIFICATIONS AND MACRO COMPARISON OF GDMS

Specifications for PFDS \ GDMS	DM-1	COGENT III	MARK IV	GIS	NIPS	PFDS Using ISAM + PL/1 + JCL + Utilities
MANDATORY						
IBM 360/50	360/50	360/40	360/30	360/40	360/40	Y
Operating System (OS) IBM	OS	OS	OS, DOS	OS	OS	Y
Vender and Cost	Auerbach Corp.	Computer Sciences Corp.	Informatics Inc. $33,000 +	IBM $400/mo.	(Dept. of Defense)	Free Package + Programming
Index Sequential Organization	Y	Y	Y	Y	Y	Y
Hierarchical File with Multi-level Arrangement	Y	Y	Y	Y	Y	Y

(Continued next page)

Legend

Y -Yes, compatible
DOS-Disc operating system

PFDS SPECIFICATIONS AND MACRO COMPARISON OF GDMS (Continued)

Specifications for PFDS \ GDMS	DM-1	COGENT III	MARK IV	GIS	NIPS	PFDS Using ISAM + PL/1 + JCL + Utilities
Update (add, delete, and modify)	Y	Y	Y	Y	Y	ISAM
Vendor Supplied IOCS	Y	Y	Y	Y	Y	Y
Scientific Library Subroutine Links	Y	Y	Y	Y	N	IBM Scientific Routines
DASD	Y	Y	Y	Y	Y	3336 2314
Procedural Language DO	#	N	EQ	Y	N	Function of Command Processor of PFDS

(Continued next page)

Legend

Y -Yes, compatible
N -No
-Need to implement
EQ -Equivalent
IOCS-Input-Output control system
DASD-Direct access storage device

PFDS SPECIFICATIONS AND MACRO COMPARISON OF GDMS (Continued)

Specifications for PFDS / GDMS	DM-1	COGENT III	MARK IV	GIS	NIPS	PFDS Using ISAM + PL/1 + JCL + Utilities
GO TO	#	NM	EQ	Y	N	Function of Command Processor of PFDS
IF	#	NM	EQ	Y	N	Function of Command Processor of PFDS
Mode of Computation: Floating Point	#	Y	Y	N	N	Feature of PL/1
Decimal	#	Y	Y	Y	N	Feature of PL/1
Integer	#	Y	Y	N	Y	Feature of PL/1

(Continued next page)

Legend

-Need to implement
NM -Need modification
EQ -Equivalent
Y -Yes, compatible
N -No

PFDS SPECIFICATIONS AND MACRO COMPARISON OF GDMS (Continued)

Specifications for PFDS \ GDMS	DM-1	COGENT III	MARK IV	GIS	NIPS	PFDS Using ISAM + PL/1 + JCL + Utilities
Operators: $= \pm$ X / EXP	#	Y	Y	Y	NM	Feature of PL/1
$\sqrt{\ }$ Log_e Trigonometric Functions	#	#	#	N	#	Feature of PL/1
Logical and Boolean	Y	Y	Y	Y	Y	Feature of PL/1
Arithmetic Expression (number of operations per statement)	#	1	1	N	#	64
Built-in Engineering Analysis	N	N	N	N	N	Within Capability of PL/1

(Continued next page)

Legend

-Need to implement
Y -Yes, compatible
NM -Need modification
N -No

PFDS SPECIFICATIONS AND MACRO COMPARISON OF GDMS (Continued)

Specifications for PFDS / GDMS	DM-1	COGENT III	MARK IV	GIS	NIPS	PFDS Using ISAM + PL/1 + JCL + Utilities
Documentation (detailed system)	NF	NF	Proprietary	Y	Not Generally Available	#
File Reorganization to Improve Efficiency	#	#	#	#	#	Read File Sequentially Onto New Storage Area Before Releasing Old Storing Area
Ease of Language Interface	Function of Chosen Language	COBOL	Restricted	Difficult	Difficult	PL/1
Missing Input Data Elements Permitted	Y	NF	N	N	NM	Feature of PL/1

(Continued next page)

Legend

NF -Not firm
Y -Yes, compatible
-Need to implement
N -No
NM -Need modification

PFDS SPECIFICATIONS AND MACRO COMPARISON OF GDMS (Continued)

Specifications for PFDS \ GDMS	DM-1	COGENT III	MARK IV	GIS	NIPS	PFDS Using ISAM + PL/1 + JCL + Utilities
Security:						
1. File	Y	Y	#	Y	Y	JCL
2. Entry, Group, Etc.	Y	Y	#	N	N	JCL
DESIRABLE						
Data Element Physical Size:						
1. Variable Length	254B		N	N	NM	255B
2. Fixed Length						
a. Numeric	254B		4B	31DD	4B	31DD
b. Alphanumeric	254B		255B	255B	255B	255B
3. Variable Name	#	29	8			31

(Continued next page)

Legend

Y -Yes, compatible
-Need to implement
N -No
NM -Need modification
Blank means unknown.

JCL -Job control language
B -Bytes
DD -Data digits

PFDS SPECIFICATIONS AND MACRO COMPARISON OF GDMS (Continued)

Specifications for PFDS / GDMS	DM-1	COGENT III	MARK IV	GIS	NIPS	PFDS Using ISAM + PL/1 + JCL + Utilities
Levels of Nesting			9	4	8	64
Temporary Hold File	Y	Y	Y	Y	NM	SYSOUT (JCL)
Update Multiple Files in One Pass	#	Y	Y	NM	N	#
Flexible Data Elements (overriding data attributes)	#	Y	N	Y	Y	Dynamic Declaration of Data Structure in Program
Data Name Directed Update	#	Y	N	N	Y	PL/1

(Continued next page)

Legend

Y -Yes, compatible
NM -Need modification
-Need to implement
N -No
Blank means unknown.

PFDS SPECIFICATIONS AND MACRO COMPARISON OF GDMS (Continued)

Specifications for PFDS \ GDMS	DM-1	COGENT III	MARK IV	GIS	NIPS	PFDS Using ISAM + PL/1 + JCL + Utilities
List Directed Update	#	Y	Y	Y	Y	PL/1
Interruption and Recovery			Y			"ON" Options of PL/1
Input Edit (error check):						
1. Maximum or Minimum Values	#	Y	Y	NM	Y	As Programmed
2. Range of Values	#	Y	Y	Y	Y	As Programmed
3. Specific Characters	#	Y	Y	Y	Y	As Programmed
4. Sequency or Identify	#	Y	Y	Y	Y	As Programmed
5. Cross Comparison	#	Y	Y	NM	Y	As Programmed

(Continued next page)

Legend

-Need to implement
Y -Yes, compatible
NM -Need modification

PFDS SPECIFICATIONS AND MACRO COMPARISON OF GDMS (Continued)

GDMS / Specifications for PFDS	DM-1	COGENT III	MARK IV	GIS	NIPS	PFDS Using ISAM + PL/1 + JCL + Utilities
Decode and Encode	NF	Y	#	Y	Y	As Programmed
Subordinate File Creation from Source File	#	Y	Y	N	N	Derived from Source File from Programming
Physical Format of the Input Data to Generate a File:						
1. Must be Specific	#	NF	N	N	N	Not Necessary
2. May be Several	#	NF	Y	Y	Y	Optional
3. May be Any	#	NF	NM	Y	N	As Programmed
Pagination	#	Y	Y	Y	Y	As Programmed

(Continued next page)

Legend

NF -Not firm
Y -Yes, compatible
-Need to implement
N -No
NM -Need modification

PFDS SPECIFICATIONS AND MACRO COMPARISON OF GDMS (Continued)

Specifications for PFDS \ GDMS	DM-1	COGENT III	MARK IV	GIS	NIPS	PFDS Using ISAM + PL/1 + JCL + Utilities
Size, Title, Line, Positioning, etc.	#	Y	Y	Y	Y	As Programmed
Statistical Functions	#	NF	N	N	Y	IBM Routines
Picture Specification (input/output)	#	Y	Y	N		PL/1
Backup Capability	#					Utilities
Dynamic Storage in Programming						AUTOMATIC, CONTROLLED, BASED, ALLOCATE, and FREE

(Continued next page)

Legend

\# -Need to implement
Y -Yes, compatible
NF -Not firm
N -No
Blank means unknown.

PFDS SPECIFICATIONS AND MACRO COMPARISON OF GDMS (Continued)

Specifications for PFDS / GDMS	DM-1	COGENT III	MARK IV	GIS	NIPS	PFDS Using ISAM + PL/1 + JCL + Utilities
OPTIONAL						
Online Configuration	#	NF	NF	Y	Y	THD Facility
Multiple Console/ Terminals	#	NF	NF	Y	Y	THD Facility
Interactive Mode (tutorial)	#	NF	NF	N	N	As Programmed
System Tallies (keeping track)	#	NF	Y	Y	Y	OS
Sorting Capability	#	Y	Y	Y	Y	Utilities

Legend

\# -Need to implement
NF -Not firm
Y -Yes, compatible
N -No
OS -Operating system

APPENDIX C

TRAFFIC LOG CODING FORM AND SAMPLE FILE OUTPUT

Job Number	File Name		Storage Medium	
C.02	TLOG (2nd Revision)		Tape	
Avg. No. Records	Fields	Characters	How Current	Date Prepared
	41	172	1970 Data	5-20-71
File Sequence			Prepared By	Reviewed By
			B. B.	
Labels				Record Source
Retention Characteristics				Page 1 of 2

Remarks The Milepoints will be out of sort in the TLOG Master File (1970 and later).

	Item No.	From To	Size	No. of Dec. Pos.	Field Char.	Label	Item Name	
	1	1-2	2		I		DISTRICT NUMBER	
	2	3-5	3		I		COUNTY NUMBER	
	3	6-9	4		I		CONTROL	
	4	10-11	2		I		SECTION	
	5	12-16	5	3	I		BEGINNING MILEPOINT	
	6	17-21	5	3	I		ENDING MILEPOINT	
*	7	22-26	5	3	I		LENGTH OF SEGMENT	
	8	27-30	4		I		HIGHWAY NUMBER	
	9	31-32	2		I		HIGHWAY SYSTEM	
	10	33-34	2		I		ADMINISTRATIVE SYSTEM	
	11	35-36	2		I		YEAR (Of Current ADT Field)	
	12	37-42	6		I		ADT (Current Year)	
*	13	43-48	6		I		ADT (Year-1)	
*	14	49-54	6		I		ADT (Year-2)	
*	15	55-60	6		I		ADT (Year-3)	
*	16	61-66	6		I		ADT (Year-4)	
	17	67-72	6		I		ADT (Year-5)	Historical ADT
*	18	73-78	6		I		ADT (Year-6)	Fields
*	19	79-84	6		I		ADT (Year-7)	
*	20	85-90	6		I		ADT (Year-8)	
*	21	91-96	6		I		ADT (Year-9)	

Job Number	File Name	Storage Medium
C.02	TLOG (2nd Revision)	Tape

Avg. No. Records	Fields	Characters	How Current	Date Prepared
	41	172	1970 Data	5-20-71

File Sequence	Prepared By	Reviewed By
Labels		Record Source
Retention Characteristics		Page 2 of 2
Remarks		

	Item No.	From To	Size	No. of Dec. Pos.	Field Char.	Label	Item Name	
	22	97-104	8		I		VEHICLE MILES, DAILY (Current Year)	
	23	105-106	2		I		ADMINISTRATIVE SYSTEM	
	24	107-108	2		I		YEAR	
	25	109-112	4	2	I		INCREASE FACTOR (%)	Design Year
*	26	113-118	6		I		ESTIMATED ADT	
*	27	119-126	8		I		ESTIMATED V.M.	
	28	127-129	3	1	I		"K" FACTOR	
	29	130-131	2		I		DIR. DIST.	
	30	132-134	3	1	I		% TRUCKS IN AADT	
	31	135-137	3	1	I		% TRUCKS IN D.H.V.	Traffic Data
	32	138-140	3		I		ATHWLD (Hundred Lbs.)	20 Year
	33	141-142	2		I		ATHWLD (% Tandem Axles)	Design Period
	34	143-147	5		I		TNWLGT 8000 Lbs. (K)	
	35	148-152	5		I		FLEX. (K) 18K Pavement Analysis	
	36	153-157	5		I		RIGID (K) One Direction	
	37	158	1		I		F.C.	
	38	159	1		I		URBAN-RURAL Functional Classification	
	39	160	1		I		CONNECT LINK	
	40	161-166	6		I		SERIAL NUMBER	
	41	167-172	6		I		ADJUSTED CURRENT YEAR ADT (Design Year System)	

* Items to be calculated or supplied by the update program.

DISTRICT - 5 MAR 1, 1971 PLANNING SURVEY DIVISION --- 1969 TRAFFIC LOG PAGE - 800
COUNTY - 152 LUBBOCK (A)

SERIAL NO.	NEXT YEAR	CONTROL SECTION	MILEPOINTS BEGIN	END	LENG	HIGHWAY NO.	SYST	ADM. SYST	R U	1969	HISTORICAL AVERAGE DA 1968	1967	1966		962	1961	1960
01620		67 15	616	1683	1067	461	3	1	R	1120	1260	0	0		0	0	0
01630		68 1	0	149	149	87	1	2	U	15305	16195	0	0		0	0	0
01640		68 1	149	563	414	87	1	2	U	15735	16615	0	0		0	0	0
01650		68 1	563	1238	675	87	1	2	U	12297	14105	0	0		0	0	0
01660		68 1	1238	2211	973	87	1	1	R	8040	10890	0	[illegible]		0	0	0
01680		68 1	2211	3210	999	87	1	1	R	6520	6500	0			0	0	0
01690		68 1	3210	4211	1001	87	1	1	R	5880	5890	0		0	0	0	0
01700		68 1	4211	4710	499	87	1	1	R	4380	4350	0		0	0	0	0
01710		68 1	4710	4830	120	87	1	1	R	4390	4350	0		0	0	0	0
01720		68 1	4830	4960	130	87	1	1	R	4420	4330	0		0	0	0	0
01730		68 1	4960	5212	252	87	1	1	R	4360	4330	0		0	0	0	0
01740		68 1	5212	5812	600	87	1	1	R	4230	4300	0		0	0	0	0
01760		68 1	6812	7336	524	87	1	1	R	4120	4080	0		0	0	0	0

DISTRICT - 5 MAR 1, 1971 PLANNING SURVEY D --- 1969 TRAFFIC LOG PA
COUNTY - 152 LUBBOCK

SERIAL NO.	1969 VEH MILE	DESIGN YEAR ADM	YR	FAC (XX.XX)	ESTIMATED ADT	V.M.	K FACT	DIR DIST	% TRUCKS IN ADT (XX.X)	IN DHV	ATHWLD 100 LBS	% TANDEM AXLES	TNWLGT 8000 LBS (K)	PAVEMENT ANALYSIS FLEX	RIDG
01620	1195	0	90	600	2530	27	100	54	162	118	97	20	211	465	555
01630	2280	0	90	540	32660	4	100	54	79	56	105	20	1369	3046	3617
01640	6514	0	90	510	32590	1	100	54	79	55	105	20	1379	3069	3644
01650	8300	0	90	860	34510	2	100	54	85	60	105	20	1437	3194	3794
01660	7823	0	90	800	21550		100	54	101	71	105	20	1079	2392	2846
01680	6513	0	90	1120	21860		100	54	111	78	105	20	1138	2518	2997
01690	5886	0	90	710	14650		100	54	117	82	105	20	867	1919	2285
01700	2186	0	90	710	10910	4	100	54	138	97	105	20	762	1682	2005
01710	527	0	90	710	1094	13	100	54	138	97	105	20	764	1687	2010
01720	575	0	90	710	110	431	100	54	138	97	105	20	769	1698	2023
01730	1099	0	90	710	10	2737	100	54	139	98	105	20	764	1686	2010
01740	2539	0	90	710	1	6324	100	54	141	99	105	20	752	1660	1978
01760	2159	0	90	710		5376	100	54	144	101	105	20	748	1650	1967
01770	5745	0	90	710		14305	100	54	145	102	105	20	746	1645	1961

APPENDIX D

ROAD LIFE (RL-1) CODING FORM

File 10.63-1 DESIGN AND CONSTRUCTION FEATURES

Width: Ribed. Shoulders R/W

Dist. Asphalt: 1st. Crs. 2nd 3rd

Dist. Aggr. 1st. Crs. 2nd 3rd

Asphalt: Kind

DESCRIPTION AND REMARKS

EXISTING WORK:

Grading	Base	Surf.	Sr.Typ.	Job	Year

New Work

TEXAS HIGHWAY DEPARTMENT
CONSTRUCTION RECORD FOR ROAD LIFE STUDY

CARD NO.
OF

This Job Retires

Contr._____ Sect._____ Job_____ (Card No._____)

Contr._____ Sect._____ Job_____ (Card No._____)

Contr._____ Sect._____ Job_____ (Card No._____)

LOCATION

Sta.

Sta.

From:

To:

Equations

Exceptions

Control No._____ Sec._____ Job_____

Highway No. State_____ U.S._____

Proj. No._____

Dist._____ Co._____

Compiled by_____ Date_____

RECORD OF OPERATIONS	
CC-1 Coded	
CC-2 Coded	
Strip Map Posted	
P.C.P. Coded	

Str. Numbers					No. of Strs.	Total Length
						Ft.

Rd.way Ft._____ - _____ = _____ Miles

1 County	2 Control	3 Section	4 Job Number	5 Update Code	6 Card Number	Part	7 Card Control	8 Travel Class	9 Highway System	10 Rural-Urban Classification	11 Federal Aid System	12 Project Class	13 Date Let: Month	Year	14 Date Compl.: Month	Year	15 Year On System	16 Surface Type	17 Kind of Work	18 Surface Cross-Section	19 Base Cross-Section	20 Shldrs.: Type	Width	21 Reinf. Lbs.: Type Treat.	22 Spacing Expans. Joints: Aggr. S.Y./C.Y.	23 Spacing Contr. Jts.: Bs. Mat'l	Stab'l	24 Cont. Curb: Skip	25 P.R.A. Code	26 Mileage Class	27 Miles Built	Skip
1 2 3	4 5 6 7	8 9	10 11 12	13 14 15	16 17	18	19	20	21 22	23 24	25 26	27 28 29	30 31	32 33	34 35	36 37	38 39	40 41	42 43 44 45 46 47	48 49 50 51	52 53 54 55 56	57	58 59	60 61	62 63 64	65	66	67	68 69 70 71	72	73 74 75 76 77	78 79 80
				002		1																										

County	Control	Section	Job Number	Update Code	Card Number	Part	Card Control	28 Subgrade: Type	Stab'l	Width	Depth	29 Miles Remaining	30 Beginning Milepoint	31 Ending Milepoint	32 Number of Items	50 Item	51 Dollars	Item	Dollars	Item	Dollars	Trailer Card	Skip
1 2 3	4 5 6 7	8 9	10 11 12	13 14 15	16 17	18	19	20 21	22 23	24 25		26 27 28 29	30 31 32 33 34 35	36 37 38 39 40	41	42 43	44 45 46 47 48 49 50 51	52 53	54 55 56 57 58 59 60 61	62 63	64 65 66 67 68 69 70 71	72	73 74 75 76 77 78 79 80
				002		2																	

County	Control	Section	Job Number	Update Code	Card Number	Part	Card Control	Item	Dollars	Item	Dollars	Item	Dollars	Item	Dollars	Item	Dollars	Item	Dollars	Skip
1 2 3	4 5 6 7	8 9	10 11 12	13 14 15	16 17	18	19	20 21	22 23 24 25 26 27 28 29	30 31	32 33 34 35 36 37 38 39	40 41	42 43 44 45 46 47 48 49	50 51	52 53 54 55 56 57 58 59	60 61	62 63 64 65 66 67 68 69	70 71	72 73 74 75 76 77 78 79	80
				002		3														

APPENDIX E

ROAD INVENTORY (RI-2) CODING FORM

Job Number	File Name	Storage Medium
A.02	RI-2 MASTER FILE	TAPE

Avg. No. Records	Fields	Characters	How Current	Date Prepared
	39	103		Dec. 1968

	Prepared By	Reviewed By
File Sequence 1. COUNTY, 2. CONTROL, 3. SECTION 4. BEGINNING MILEPOINT, 5. ENDING MILEPOINT	B.F.B.	
Labels LRECL=103,BLKSIZE=1030		Record Source
Retention Characteristics		Page 1 of 2
Remarks		

Item No.	From To	Size	No. of Dec. Pos.	Field Char.	Label	Item Name	
1	1-2	2		I	DIST	DISTRICT NUMBER	
2	3-5	3		I	CONTY	COUNTY NUMBER	
3	6-9	4		I	CONTL	CONTROL	
4	10-11	2		I	SHD	SHD SECTION NUMBER	
5	12-16	5	3	I	ISTART	BEGINNING MILEPOINT	
6	17-21	5	3	I	IEND	ENDING MILEPOINT	
7	22	1		I	ISTAT	HIGHWAY STATUS	
8	23-24	2		I	ADMI2	AMINISTRATIVE SYSTEM	
9	25-26	2		A	FASY2	FEDERAL AID SYSTEM	
10	27-28	2		A	INFE2	IN FEDERAL RESERVATION	
11	29-33	5		I	ICTY	CITY NUMBER	
12	34-37	4		A	LOC24	RIGHT OF WAY WIDTH	MAIN LANES
13	38-40	3		A	LOC27	ROAD BED WIDTH	MAIN LANES
14	41-43	3		A	SURFWD	SURFACE WIDTH	MAIN LANES
15	44	1		A	LOC31	BASE TYPE	MAIN LANES
16	45-46	2		A	LOC32	SHOULDERS TYPE	MAIN LANES
17	47-48	2		I	SURFTP	SURFACE TYPE	MAIN LANES
18	49	1		A	COMB	COMBINATION	MAIN LANES
19	50	1		I	DESIGN	DESIGN TYPE	MAIN LANES
20	51-52	2		A	KOC37	NUMBER LANES	MAIN LANES
21	53	1		A	LOC68	ACCESS	MAIN LANES

Job Number	File Name RI-2 MASTER FILE	Storage Medium TAPE

Avg. No. Records	Fields	Characters	How Current	Date Prepared
File Sequence			Prepared By B.F.B	Reviewed By
Labels				Record Source
Retention Characteristics				Page 2 of 2
Remarks				

Item No.	From To	Size	No. of Dec. Pos.	Field Char.	Label	Item Name
22	54-55	2		A		TYPE FRONTAGE ROADS [2]
23	56-58	3		A		WIDTH FRONTAGE ROADS
24	59-60	2		A		NUMBER LANES FRONTAGE ROADS
25	61	1		A		NUMBER ROADS FRONTAGE ROADS
26	62-63	2		A	LOC56	GRADES, NUMBER, 3-5%
27	64-65	2		A	LOVER3	GRADES, LENGTH, 3-5%
28	66-67	2		A	LOC60	GRADES, NUMBER OVER 5%
29	68-69	2		A	LOVER5	GRADES, LENGTH OVER 5%
30	70-71	2		A	LOC64	CURVES, NUMBER
31	72-73	2		A	LCURVE	CURVES, LENGTH
32	74-75	2		A	SYST2	HIGHWAY SYSTEM
33	76-79	4		A	HWY	HIGHWAY NUMBER
34	80	1		I	ISR	ROUTE SERIAL NUMBER [2]
35	81	1		I	IDR	DIRECTION OF ADJUSTMENT [2]
36	82-86	5	3	I	IADJ	AMOUNT OF ADJUSTMENT [2]
37	87-92	6	3	I	NSTART	ADJUSTED BEGINNING MILEPOINT [2]
38	93-98	6	3	I	NEND	ADJUSTED ENDING MILEPOINT [2]
39	99-103	5	3	I	LENGTH	LENGTH OF SECTION
[2]	NOT IN	RECORD	AT THIS	TIME.		

THE AUTHORS

Oren G. Strom, an active duty U. S. Air Force Civil Engineer, has recently completed a graduate engineering research program at The University of Texas at Austin. His experience includes 18 years of military engineering management, both in the U. S. and overseas, and one year of civilian employment with the Wisconsin State Highway Commission.

W. Ronald Hudson is an Associate Professor of Civil Engineering at The University of Texas at Austin. He has had a wide variety of experience as a research engineer with the Texas Highway Department and the Center for Highway Research at The University of Texas at Austin and was Assistant Chief of the Rigid Pavement Research Branch of the AASHO Road Test. He is the author of numerous publications and was the recipient of the 1967 ASCE J. James R. Croes Medal. He is presently concerned with research in the areas of (1) analysis and design of pavement management systems, (2) measurement of pavement roughness performance, (3) slab analysis and design, and (4) tensile strength of stabilized subbase materials.

James L. Brown is a Senior Designing Engineer in the Pavement Design Section of the Texas Highway Department, Highway Design Division. He has a variety of experience at both the district and division levels and has been actively involved in the development and pilot implementation of the Flexible Pavement System since its conception. He is the author of several publications in highway engineering research and is Area Coordinator for the Pavement Research Advisory Committee.